

H. O. MISC. 16331



FIELD REPORT

OCEANOGRAPHIC OBSERVATIONS

U.S. NAVY ANTARCTIC EXPEDITION

1954-1955

U.S.S. ATKA (AGB-3)

MARCH 1956



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U 642

U. S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON, D. C.

ABSTRACT

Results of oceanographic operations during the U.S. Navy Antarctic Expedition 1954-1955 are presented. In the Ross Sea area water temperatures off Kainan Bay were markedly different because of the relatively thin layer of fast ice as compared with the thick shelf ice at Little America. Low salinities were found near the shelf ice at Little America while at Kainan Bay low salinity water was pushing in from the north.

In Bransfield Strait water mass characteristics observed in the eastern part of the strait showed marked differences from those observed in the western portion of the strait.

In the Weddell Sea observations near the shelf ice along the eastern edge of the sea disclosed warmer high salinity water from the Indian Ocean striking the Antarctic Coast. After being cooled over the shallow continental shelf this water sinks along the continental slope and flows out to the north as a deep, strong, cold-water current of high salinity.

Shallow water sound channels found in the Ross Sea compare favorably with similar shallow water sound channels found in the Bering Sea and eastern Arctic region. In Bransfield Strait both depth of the axis and velocities found along the axis indicate a transition between contrasting water masses. In the Weddell Sea sound channels were not discernable.

The Antarctic Convergence is depicted by horizontal plots of air temperature, and water temperature, salinity, and density obtained from bucket samples. Vertical water temperature sections constructed from bathythermograph observations across the convergence are presented. The zone of convergence was found farther north in the South Atlantic Ocean than in the South Pacific Ocean. Also, greater mixing was apparent in the surface layer to the north of the convergence on the Atlantic side.

Analyses of bottom samples show marked differences on the Atlantic side of the Antarctic Continent as compared to the Pacific side. Magnetic grains were most prevalent in the Bellingshausen Sea and Bransfield Strait, but were not abundant in the Antarctic area. Radioactivity appeared to be nonexistent, and organic carbon content was low.

Occurrence and depth of the deep scattering layer were observed throughout the cruise. Characteristics of the layer are compared with those observed by the USS HENDERSON in 1946-1947 and the French Ship COMMANDANT CHARCOT in 1948-1949.

Observations of snow temperature, density, and hardness and of snow stratigraphy at locations on the fast and shelf ice are presented and discussed.

The names of the following geographic features are not officially approved by the United States Board on Geographic Names: Admiral Byrd Bay, Atka Bay, Observer's Ice Tongue, and Penguin Bay.



FOREWORD

The U. S. Navy Antarctic Expedition 1954-1955 was the first venture of the Navy in the Antarctic since 1948. The primary objective of the cruise was a reconnaissance survey of the Ross and Weddell Sea areas to select sites for future bases during the International Geophysical Year program. Secondary projects consisted of scientific investigations, largely in the geophysical sciences. Personnel from the U. S. Navy Hydrographic Office collected hydrographic and oceanographic data and assisted in carrying out the scientific program of the expedition. The analyses of oceanographic and other closely related data are presented in this report.

W. H. Mearns



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I. INTRODUCTION

A. Purpose

The primary objective of the U. S. Navy Antarctic Cruise 1954-1955 was a reconnaissance survey of the general regions of the Ross and Weddell Seas to select sites for future bases for the International Geophysical Year program. As secondary projects carrying lower priority, investigations were carried out in such fields as distribution and intensity of cosmic rays, radio reception, meteorology, snow compaction for airstrips, and oceanography. Oceanographic investigations were carried out on a not-to-interfere basis on the trip to the Antarctic and on the return voyage. In the area of operations, oceanographic observations were undertaken whenever it was possible to stop the ship for periods of two hours or more. Bottom sediment cores were obtained when it was possible to stop the ship for half-hour periods, ice conditions permitting.

The first U. S. Navy icebreaker venture into the Antarctic was in 1946-1947 in connection with Operation HIGHJUMP. On the expedition the icebreakers USS BURTON ISLAND (AGB-1) and the USCGC NORTH-WIND (WAGB-282) took bathythermograph observations and, along with other vessels of Operation HIGHJUMP, occupied a few scattered oceanographic stations in the area extending from the Ross Sea westward to the Bunger Lakes area. The following year the U. S. Navy icebreakers USS BURTON ISLAND (AGB-1) and USS EDISTO (AGB-2) made a survey from the Bunger Lakes area to Marguerite Bay in the Palmer Peninsula. Some oceanographic work was accomplished, consisting mainly of bathythermograph casts. The Navy icebreaker USS ATKA (AGB-3) was the first United States vessel to enter the Antarctic regions since 1948.

B. Summary of Oceanographic Operations

The USS ATKA (AGB-3) left Boston on 1 December 1954 enroute to New Zealand and the Antarctic (fig. 1). The ATKA returned to Boston on 12 April 1955 after steaming over 28,000 miles during a period of almost four and a half months.

Bathythermograph casts were made every 4 hours from Boston to Panama. Upon leaving Panama, bathythermograph casts were increased (on 12 December) to one cast hourly, a schedule that was maintained throughout the cruise except when the ship was in shoal water or in ice. BT casts were made at 4-hourly intervals when conditions permitted while in ice. Hourly BT casts were resumed when open water was reached on the return trip north from Antarctica and were continued as far north as 20° N. During the remainder of the trip casts were made every 4 hours until near Boston. Near the Antarctic

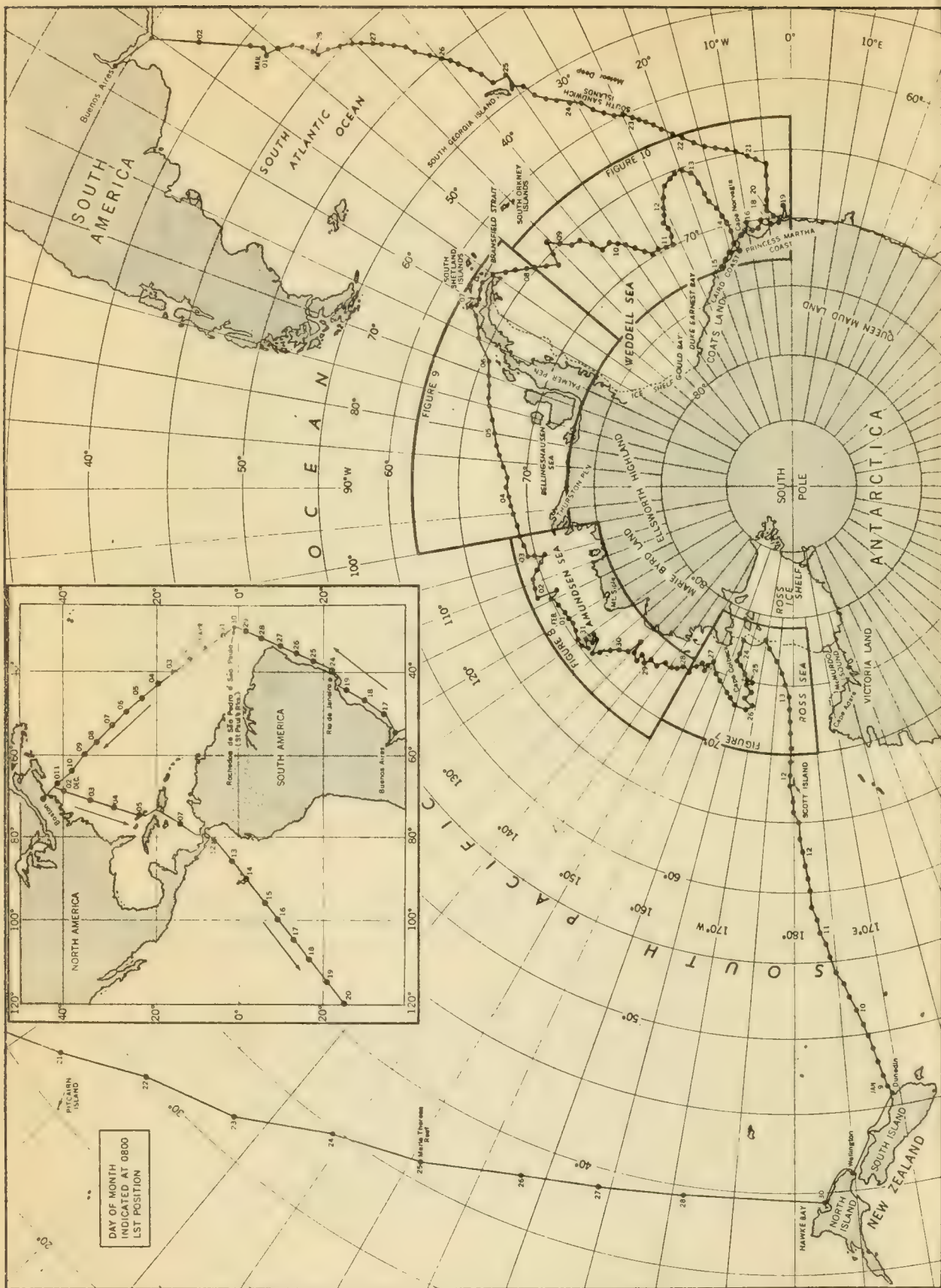


Figure 1. Track Chart USS ATKA - Navy Antarctic Expedition 1954-1955.

Convergence, BT casts were increased to half-hourly intervals. Surface water samples for salinity and deuterium oxide (heavy water) determinations were taken hourly commencing several hours before the marked change in temperature. Unfortunately, enroute to Antarctica, the BT casts had to be discontinued for a period following the drop in temperature because of rough seas. Fourteen hundred drift cards supplied by the U.S. Fish and Wildlife Service were released at the convergence enroute; the remaining 1,100 drift cards released after crossing the convergence on the return trip.

Oceanographic station data were obtained at 13 stations in Antarctic waters to provide information on temperature, salinity, density, and sound velocity characteristics over the continental slopes of the Ross and Weddell Sea areas, particularly near the shelf ice face and seaward for 50 miles, and in Bransfield Strait to study differences in water mass structure and composition. Daily surface water samples were obtained commencing at Panama and continued with few interruptions throughout the cruise.

Bottom cores were obtained to determine the physical and chemical characteristics, distribution, origin, and depositional characteristics of sediments surrounding the Antarctic Continent. Transparency measurements were made where light intensity permitted. Plankton tows, although not a part of the oceanographic program, were made as a matter of interest whenever possible. Continuous sonic soundings were made during the cruise and analyzed to determine the occurrence and characteristics of the deep scattering layer. Observed ice conditions were plotted. Results of snow and ice tests at snow pits and from ice cores on the shelf and fast ice were report upon.

Oceanographic results of the cruise have been divided for the sake of convenience into three main areas, the Ross Sea, Bransfield Strait, and the Weddell Sea.

C. Participating Personnel

Sixteen observers were aboard the ATKA during the cruise, representing such widely diversified activities as the Army, Navy, Marine Corps, Air Force, Weather Bureau, Geological Survey, and the New York Times. The following personnel represented the Navy Hydrographic Office:

Charles W. Culkin (Photogrammetrist)
Willis L. Tressler (Oceanographer)
Charles M. Williams (Cartographer)

II. ROSS SEA AREA, OCEANOGRAPHY

A. General

The Ross Sea is formed by a deep impression into the Antarctic Continent between 160° W. and 160° E. The eastern side is formed by the Edward VII Peninsula with Cape Colbeck at its most northern tip, to the west it is bounded by Victoria Land which terminates to the north at Cape Adare. The Ross Sea is approximately 500 miles broad and some 700 miles deep; the southern half of the sea is completely filled by shelf ice, the famous Ross Shelf Ice forming the Ross Ice Barrier which extends for 400 miles along its northern edge. The Ross Ice Barrier extends from McMurdo Sound and Ross Island eastward to Okuma Bay and Edward VII Peninsula and continues as the ice shelf along the peninsula around Cape Colbeck.

During the winter months (June through August), the Ross Sea freezes over but as spring and summer approach, southerly winds and currents break up the fast ice and push it to the north. During the summer months (December through February), there is always a wide belt of ice-free water extending from the shelf ice face northward about one hundred miles to the edge of the pack. The pack extends northward to just south of Scott Island and is variable in its extent and consistency from one season to another. In some rare summer seasons, ships have not encountered any pack ice along the 180° meridian; at other times pack ice presents a formidable barrier across the entrance to the southern part of the Antarctic seas. By January, in typical seasons, the icepack is broken, rotten, and easily traversed by modern, powerful ships. The open water along the face of the Ross Ice Shelf commonly continues northward along Edward VII Peninsula as far as Cape Colbeck. In some seasons a lead of open water extends eastward from Cape Colbeck for a considerable distance along the coast of Marie Byrd Land.

The Ross Sea averages 500 to 1,000 meters in depth and its waters are cut off from the open ocean by the Pennell Bank, which is considerably less than 500 meters deep and effectually retains bottom water to the south. Hence there is no cold bottom current running out of the Ross Sea such as we have in the Weddell Sea. Outside of the Ross Sea to the north, the general surface current trend is from west to east. A westerly setting current runs along the ice shelf face and out along the coast of Victoria Land and around Cape Adare. This current has a drift amounting to as much as 3 knots along the Ross Ice Shelf. In general, the Antarctic surface water is cold to a depth of 100 to 250 meters and lies on top of a warmer, more saline layer. Near the ice in the summer months considerable variation in salinity and temperature occurs, which is caused by melting ice.

B. Physical Properties

Stations 1, 2, 3, and 4 (fig. 2), taken off Little America from the edge of the ice shelf in the former Bay of Whales seaward in a general northwesterly direction, indicate the conditions prevailing in the water close to the edge of the shelf ice. The most seaward station was barely 25 miles north of the Ross Ice Barrier and about 40 miles from the southernmost end of the former Bay of Whales. Off Kainan Bay, 30 miles to the east of the Bay of Whales, stations 5, 6, and 7 (fig. 3) were completed extending from the edge of the fast ice of Kainan Bay to the outermost station some 15 miles north of the shelf ice face. Stations 6 and 7 were taken in open water. Station 5 was taken in broken pack ice of about 4/10 coverage.

1. Temperature

Off Little America, warmer water extended from the surface to about 100 meters depth, below which the water mass showed a temperature of -1.75°C . The water above 100 meters depth gradually warmed to a temperature slightly above 0°C . near the surface and showed a marked drop near the edge of the fast ice. Temperatures in the section off Kainan Bay were markedly different because of the relatively thin layer of fast ice as compared with the thick shelf ice at Little America. Water of a temperature of -1.75°C . or less was found only near the bottom at depths approaching 600 meters, except at station 5 where cold water rose to the 300 meter depth and a sharp temperature gradient was present between 50 and 75 meters. This marked temperature gradient was probably caused by melting ice of the pack, and by colder water being pushed in from the north as indicated by the salinity and density profiles.

2. Salinity

Salinity values, in the Bay of Whales section, showed a regular increase from the surface to the bottom at the outer stations. There was a gradual drop in salinity values shoreward to the most southern station, where a marked decrease in salinity was noted at all depths. This was caused by melt water from the ice shelf face aided by the westerly setting current, which carries melt water along the face of the whole Ross Ice Shelf. Maximum salinity (34.60 ‰) was found below 500 meters depth. Minimum salinity at Little America was 34.07 ‰ . Surface water salinities at the Kainan Bay section were lower than at the Bay of Whales area and showed an even progression with depth right in to the edge of the fast ice, except at the outermost station. Here a mass of lower salinity water was pushing in from the north below 50 meters depth. Salinity in the Kainan Bay area ranged from a low of 33.46 ‰ at the surface to 34.60 ‰ close to the bottom at a depth of 600 meters.

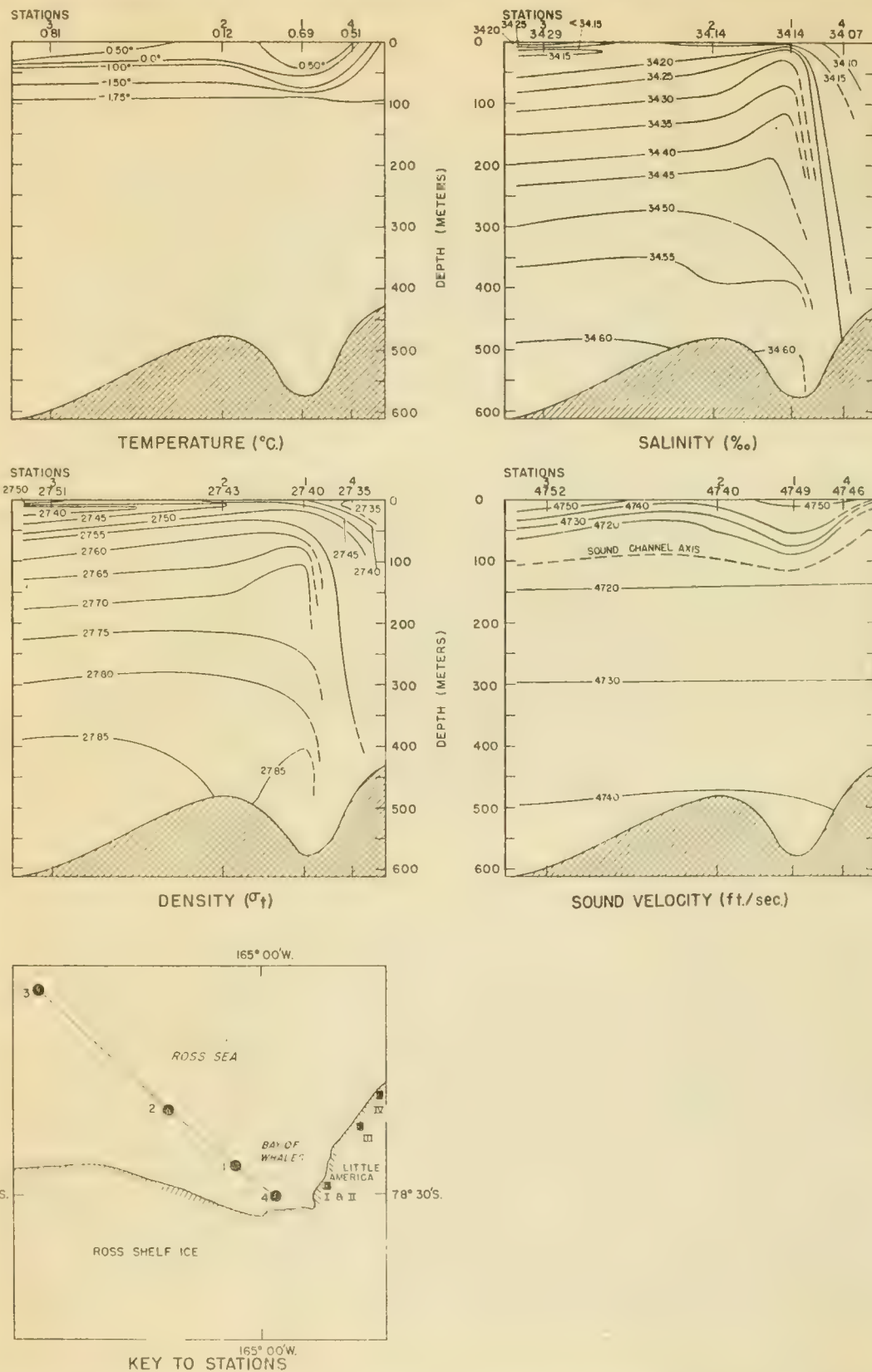
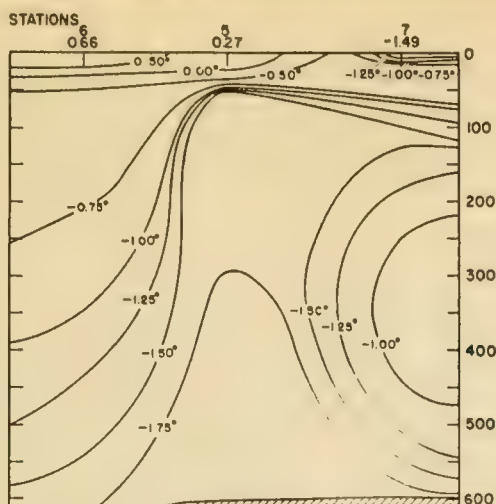
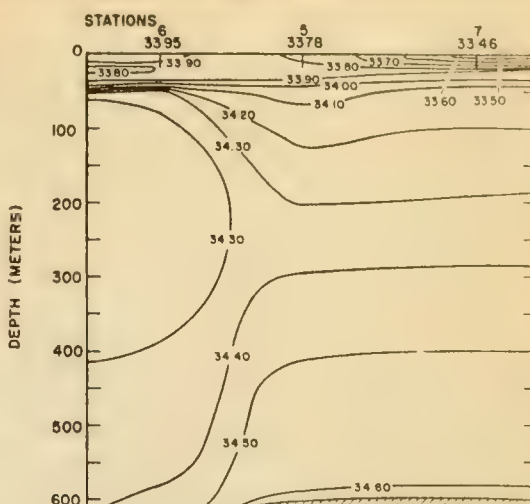


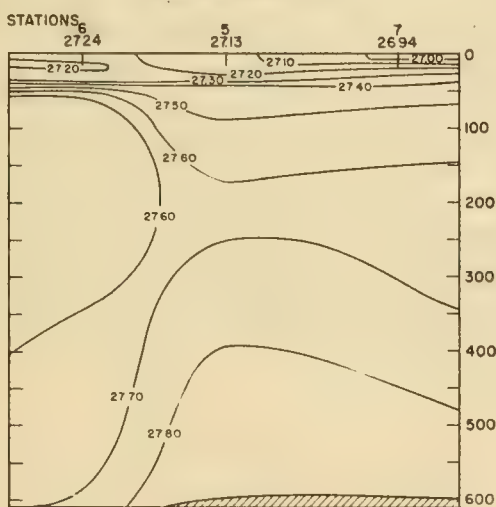
Figure 2. Vertical Distribution of Temperature, Salinity, Density, and Sound Velocity in Ross Sea (Bay of Whales) January 1955.



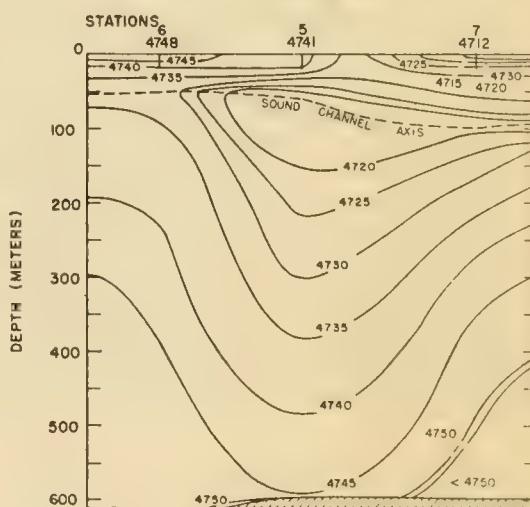
TEMPERATURE ($^{\circ}\text{C}$)



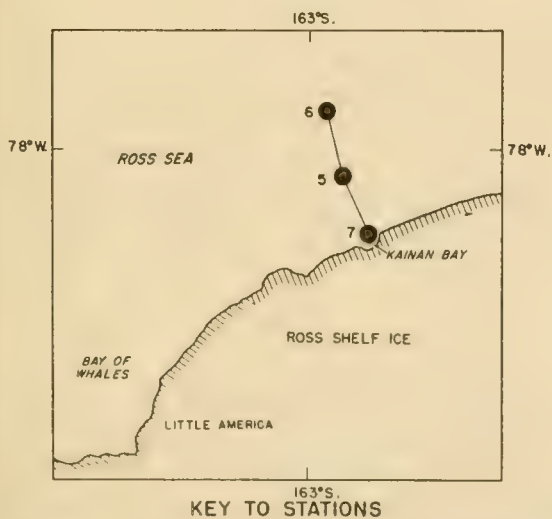
SALINITY (‰)



DENSITY (σ_t)



SOUND VELOCITY (ft/sec)



KEY TO STATIONS

Figure 3. Vertical Distribution of Temperature, Salinity, Density, and Sound Velocity in Ross Sea (Kainan Bay) - January 1955.

3. Density

Densities followed almost identical patterns with salinities at each area. In the Bay of Whales a sharp drop in both salinity and density was observed near the shelf ice face, and in Kainan Bay a mass of water having lower salinity and lower density was pushing in from the north.

4. Sound Velocity

In the Bay of Whales area sound velocities showed regular contours shoreward with a slight upward trend at the station nearest shore because of lower salinities near the shelf ice edge. Sound velocity decreased rapidly from the surface to about 100 meters depth and then slowly increased to the bottom at 600 meters. A well defined sound channel axis existed between 50 and 100 meters depth. This compares favorably with similar shallow sound channels found in the Bering Sea and in the eastern Arctic. In Kainan Bay, sound velocities were of the same order of magnitude as at Little America. However, below 300 meters the velocities found at station 5 were much lower than those found at equivalent depths at stations 6 and 7. This marked decrease in velocity may be accounted for by the cold water extending toward the surface at station 5. The sound channel axis was present between 50 and 100 meters, as at Little America. However, approaching shore a difference in the depth of the sound channel was observed. The depth of the sound channel at Little America remained at about 100 meters until shore where there was a marked upward rise to 50 meters. At Kainan Bay the reverse was true; the sound channel dropped from 50 meters depth in the two seaward stations to 100 meters at the station next to the fast ice of the bay.

III. BRANSFIELD STRAIT AREA, OCEANOGRAPHY

A. General

This comparatively narrow passage to the north of the Palmer Peninsula averages 60 miles in width and extends for approximately 200 miles from Brabant Island in the west to D'Urville Island in the east, both islands forming part of the southern boundary of the strait. To the north the strait is bounded by the South Shetland Islands of which the most famous is Deception Island lying to the west. Bransfield Strait has a reputation for rough and foggy weather but is almost always free of ice for the greater part of the summer. On very rare occasions ice has blocked Deception Island so that ships have not been able to reach it. The strait has two depressions, the deepest of which lies between Gibbs Island and Deception Island and varies from 1,500 to 1,800 meters in depth. South of Deception Island is a smaller depression with a maximum depth of 1,300 meters.

In Drake Passage to the north, the waters are moving eastward and are much warmer than the water in Bransfield Strait. Some of the Drake Passage water apparently flows south through Boyd Strait and into the smaller depression from which it flows northeastward into the main depression. A bottom stream of cold water from the Weddell Sea also flows westward along the southern shores. This current is the product of the deep cold bottom water which originates in the Weddell Sea, flows down the continental slope and then spreads north and west.

B. Physical Properties

Three stations were selected to form a section through the strait (fig. 4) which would show the warm water to the west and possibly the colder Weddell Sea water from the east and south. Hence, the western station (station 8) was located southeast of Boyd Strait and slightly west of Deception Island, station 10 was located north of D'Urville in the southeast corner of Bransfield Strait, and a third station (station 9) was located between the other two stations in the middle of the strait. As might be expected, the two eastern stations show similarities in the water mass structure and composition, while there is a marked change at the Deception Island station which is influenced by the Drake Passage water flowing southward through Boyd Strait.

1. Temperature

Water having temperatures below 0°C. is present below a depth of 100 meters at both easterly stations, but disappears to the west before Deception Island is reached, apparently flowing south along the southern shores of the strait. The coldest water observed at the D'Urville Island station was -0.75° C. at a depth of just below 100 meters; at

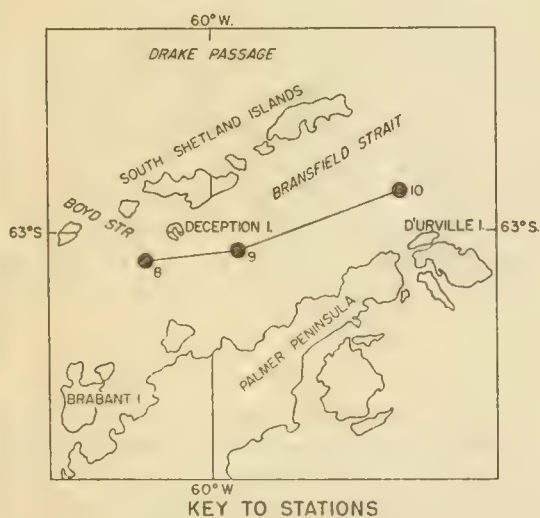
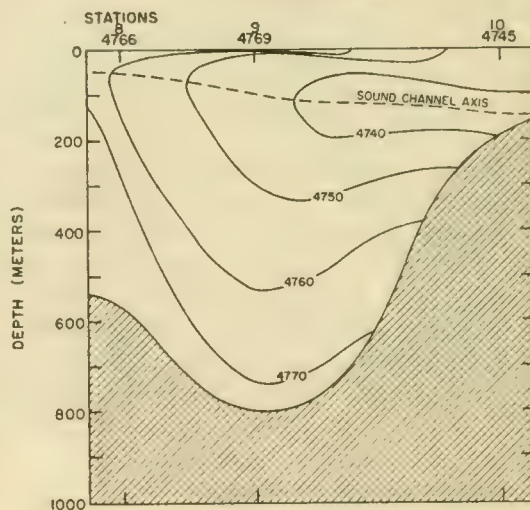
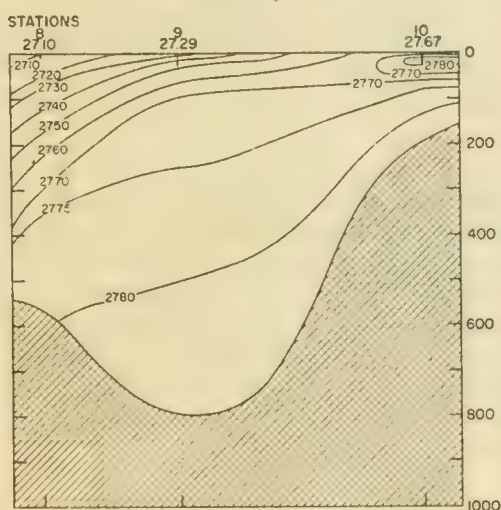
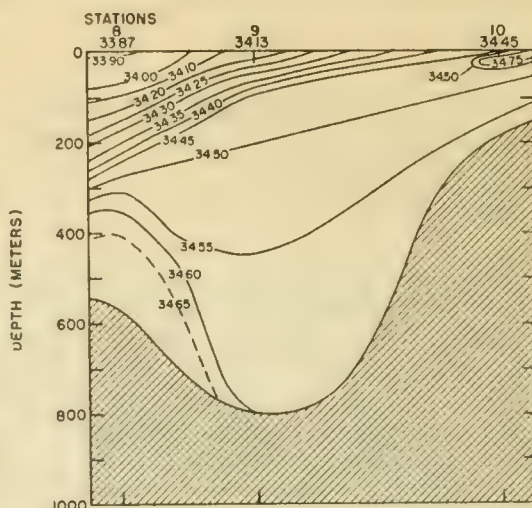
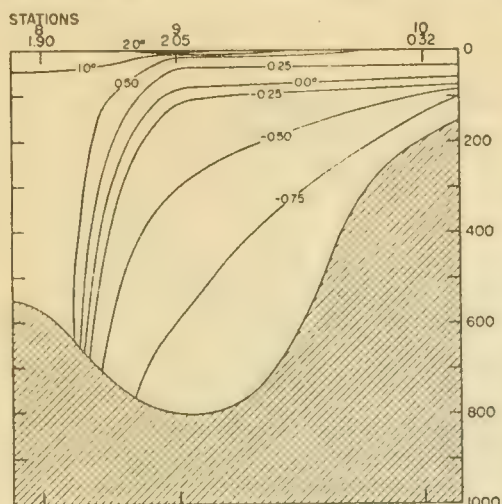


Figure 4. Vertical Distribution of Temperature, Salinity, Density, and Sound Velocity in Bransfield Strait - February 1955.

station 9 this water was found at 600 meters depth. Some warm ($+ 2.0^{\circ}$ C.) water was observed at the surface at station 9. At Deception Island (station 8) all temperatures observed were above 0° C. The temperature of the surface water at the Deception Island station was $+ 1.90^{\circ}$ C., a water temperature of $+ 1.0^{\circ}$ C. was observed at about 40 meters, and very little change in water temperature was observed from that depth to the bottom where the observed temperature was $+ 0.89^{\circ}$ C. at a depth of 575 meters. Surface water temperatures in the Bransfield Strait were above 0° C. along the observed section to a depth of 50 meters at the time the stations were occupied (7 February 1955).

2. Salinity

Surface and upper water salinities were higher at the eastern end of Bransfield Strait and decreased noticeably to the westward. A small tongue of high salinity water (34.77 to 34.99 ‰) was observed between 15 and 35 meters depth at the D'Urville Island station. This probably represented Weddell Sea water flowing in from the east and south. No trace of water of high salinity (34.60 ‰ or higher) was observed in the bottom waters of the D'Urville Island station, but salinity values greater than 34.60 ‰ were observed below 350 meters at Deception Island. Steep vertical salinity gradients were present at stations 8 and 9, the sharply defined gradients extending to depths of 300 and 100 meters, respectively.

3. Density

Density showed much the same pattern as salinity, with a tongue of high density water (27.93 to 28.11) pushing in from the east at the D'Urville Island station. Also, marked vertical density gradients were present to depths of 300 and 100 meters at stations 8 and 9, respectively. Density values ranged from 27.10 at the surface at Deception Island to 28.11 at 15 meters at D'Urville Island.

4. Sound Velocity

A sound channel was present through Bransfield Strait. Depth of the axis varied from 50 meters at station 8 to 100 and 150 meters at stations 9 and 10, respectively. Sound velocity along the axis decreased from 4,754 ft./sec. at station 9 to 4,737 ft./sec. at station 10. Both the depth of the axis and the velocities found along the axis indicate the transition from the warmer inflow through Drake Passage in the northwest to the colder Weddell Sea water in the southeast. A shallow layer sound channel was present in the upper 20 meters at stations 9 and 10 but is not shown on the sound velocity profile.

IV. WEDDELL SEA AREA, OCEANOGRAPHY

A. General

This large indentation in the Atlantic side of the Antarctic Continent lies between the Palmer Peninsula to the west and Coats Land to the east. The southern boundary remains doubtful because of incomplete exploration. Recently, the Argentines have reported exploring the coast from Duke Ernst Bay as far as Gould Bay. To the north, the Weddell Sea is bounded by the South Shetland, South Orkney, and South Sandwich Islands. From the tip of Palmer Peninsula at D'Urville Island to Cape Norvegia in Coats Land, the Weddell Sea is approximately 1,100 miles long; from north to south it is about 800 miles wide. The southern portion of the Weddell Sea is occupied by an extensive ice shelf, which is a continuation of the shelf ice which extends along Coats Land. Until recently a large ice mass, the Stancomb-Wills Ice Tongue, extended into the sea along the Caird Coast. However, in 1955, the Argentines reported that this prominent feature had disappeared.

The outer, main portion of the Weddell Sea is considerably deeper than the Ross Sea and reaches extreme depths of nearly 5,000 meters. The southern portion has been only sketchily sounded (mainly as a result of the drift of the ENDURANCE) but appears to be much more shallow (300 to 400 meters), with a regularly sloping bottom along the east coast of the Palmer Peninsula. To the north is the great Meteor Deep, which drops off to 8,200 meters. Within 150 miles of the Meteor Deep (61.5° S. 23° W.) is an unnamed rock about 20 feet high and 400 feet long, which was first reported in 1928 and was confirmed in 1930.

The extent of the pack ice in the Weddell Sea appears to be extremely variable from one season to another. In general, the sea is ice filled during the summer months, especially to the north and west. Later in the season a warm current, originating in the Indian Ocean, sweeps southwestward into the Weddell Sea and breaks up the pack. During most seasons, ships can enter the area without encountering much ice by going to the east and coming onto the coast by Cape Norvegia on Queen Maud Land, or even farther eastward. There is commonly an open shore lead along Coats Land as far west as Duke Ernst Bay. In 1955, the SAN MARTIN reported this lead to be 50 miles in width and open throughout the month of January. This lead also extends eastward along the Princess Martha Coast. Ships taking advantage of the open water along Coats Land run some risk of being closed in by the shifting pack which may be blown in from the north.

A westerly setting current follows along Coats Land from Cape Norvegia and, together with the prevailing winds, largely accounts

for the open water along this coast. This is an extension of the current originating in the Indian Ocean, where it attains high salinity and considerable heat before flowing southward until it strikes the Antarctic Coast. On the shallow continental shelf it is cooled, follows the continental slope down to the deeper portions of the Weddell Sea, and then flows out to the north as a deep, strong, cold-water current of high salinity. It is a portion of this current which rounds the tip of the Palmer Peninsula and flows westward along the southern shores of Bransfield Strait. The current setting along the eastern side of the Palmer Peninsula packs the ice in solidly along this coast, so that no ship has been able to approach the Weddell Sea from this direction.

B. Physical Properties

Oceanographic stations were not occupied in the main body of the Weddell Sea during the present cruise, and the few stations that were taken were along the eastern edge of the sea on the Princess Martha Coast. The coast along this region is obscured by an ice shelf and shelf ice face similar to that of the Ross Sea. A 2-station section was made at Atka Bay (fig. 5), which is located about 60 miles east of Norsel Bay and Maudheim. A single station was occupied at the edge of the fast ice of Admiral Byrd Bay (fig. 6). The Atka Bay stations were 65 and 800 meters deep respectively, while the Admiral Byrd Bay station was taken in 2,250 meters. There is little similarity between the two locations, but they do provide an indication of conditions existing at and within 10 miles of the shelf ice on this side of the Antarctic Continent.

1. Temperature

In Atka Bay, water temperature was below 0°C . from the surface to the bottom at both stations, the lowest temperatures being found at the bottom. Temperatures in the surface layer to a depth of 50 meters were similar at both stations, temperature differences in this layer generally amounting to less than 0.10°C . Below 50 meters the vertical gradient was more pronounced at the inshore station, and the isotherms followed the narrow continental shelf and slope. Temperatures at the bottom varied only 0.01°C . (-1.32° and -1.33°C . at stations 11 and 12, respectively), indicating the seaward flow of cold water over the bottom of the continental slope. At Admiral Byrd Bay water temperatures were below 0°C . from the surface down to 1,400 meters. The coldest water was found between the surface and 500 meters, with the minimum temperature of -1.62°C . occurring at 400 meters. Below 1,400 meters, the temperature of the water rose with increasing depth, a temperature of $+1.50^{\circ}\text{C}$. being observed in bottom water at a depth of 2,000 meters.

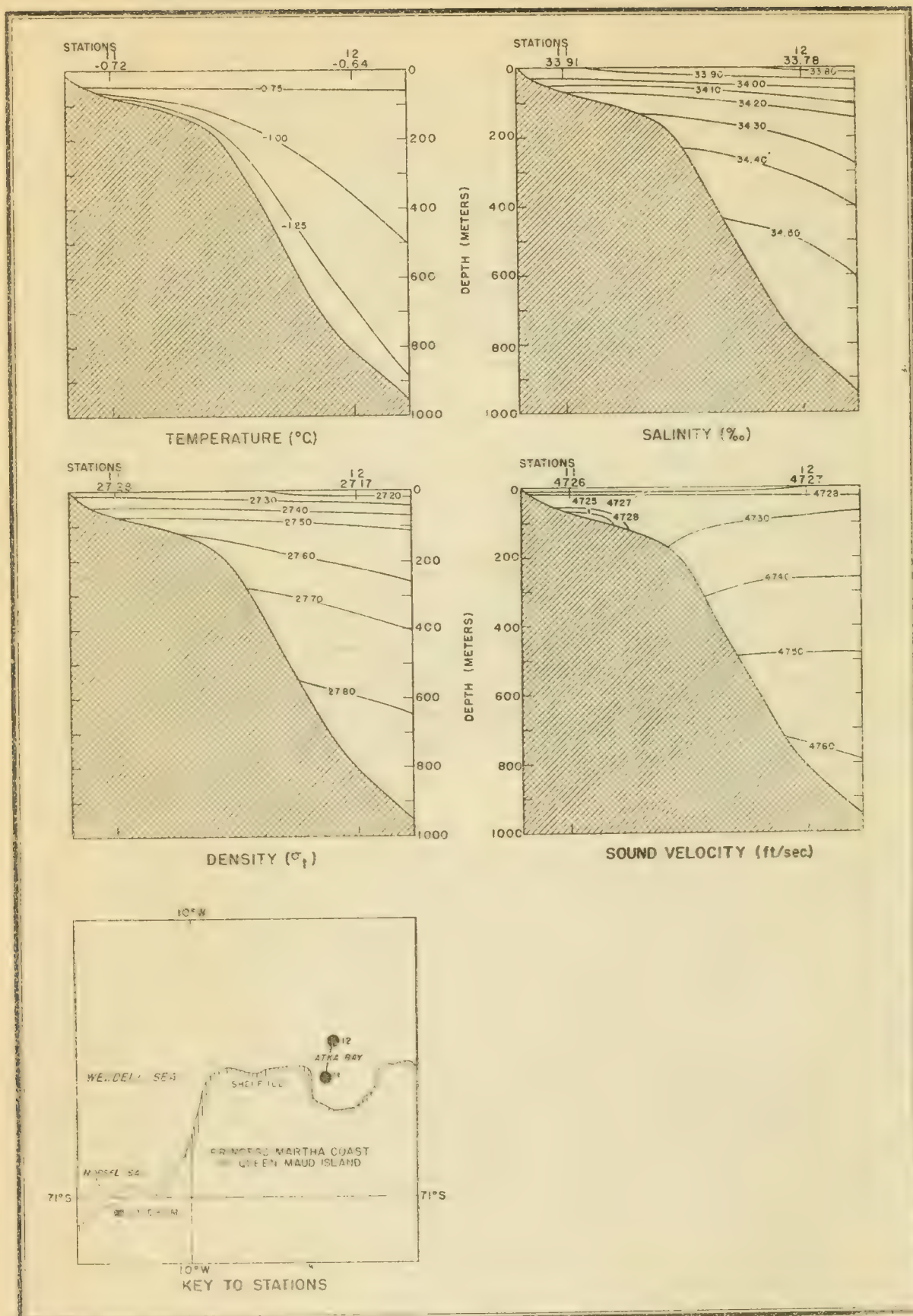


Figure 5. Vertical Distribution of Temperature, Salinity, Density, and Sound Velocity in Alka Bay - February, 1955.

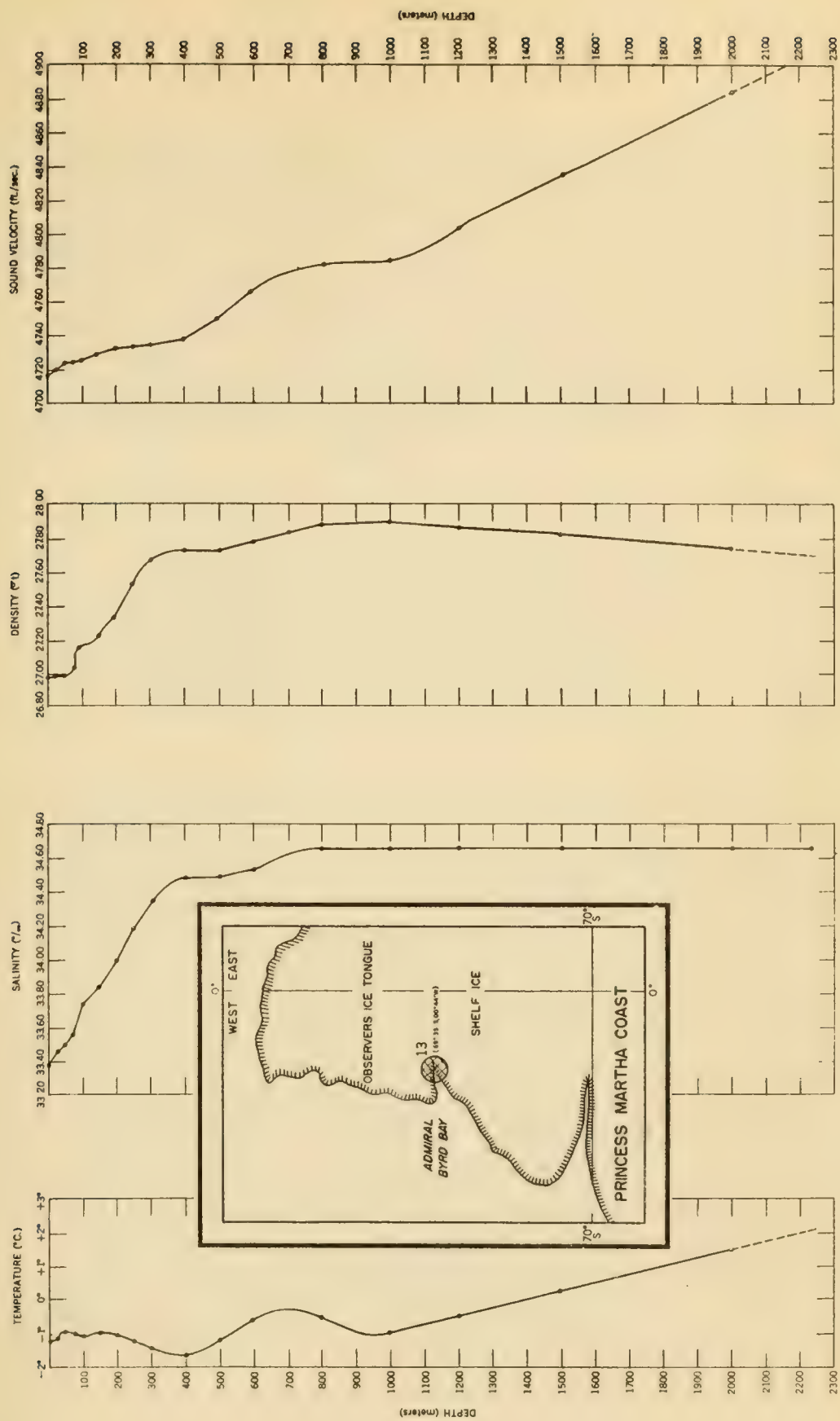


Figure 6. Oceanographic Station Plot of Temperature, Salinity, Density, and Sound Velocity in Admiral Byrd Bay - February 1955.

2. Salinity

The salinity profile for Atka Bay is similar to that of temperature, the isolines following a horizontal pattern between stations in the upper 65 meters and then gradually bending to conform to the contour of the continental shelf and slope. Actual values were ordinary, no highly saline water appearing at the time of sampling. The minimum value of 33.78 ‰ was observed at the surface while the maximum salinity (34.56 ‰) was found at a depth of 800 meters. At Admiral Byrd Bay, the salinity of the water increased from the surface to 800 meters, and isohaline conditions existed below that depth. A minimum salinity of 33.39 ‰ was observed at the surface and a maximum salinity of 34.67 ‰ was found from 800 meters to the bottom (2,250 meters).

3. Density

The density profiles for Atka Bay also are similar to the salinity and temperature profiles in the configuration of the isolines. A minimum density of 27.17 was observed at the surface and the maximum density of 27.83 at 800 meters. In Admiral Byrd Bay density of the water increased from a minimum of 26.88 at the surface to 27.90 at 1,000 meters and below that depth decreased only slightly.

4. Sound Velocity

In Atka Bay the sound velocity profile in the surface layer, to a depth of 50 meters, was similar at stations 11 and 12, a slight increase in sound velocity with increasing depth being noted at both stations. At the inshore station (11), over the continental shelf, a marked decrease in sound velocity occurred between 50 meters depth and the bottom at 65 meters. The minimum sound velocity was 4,722 ft./sec. at the bottom. At station 12, sound velocity continued to increase until a maximum velocity of 4,767 ft./sec. was reached at the bottom depth of 800 meters. The acoustic properties, depicted in the sound velocity profile, agree favorably with the thermal characteristics of the water shown in the vertical temperature profile, where nearly isothermal conditions were found in the surface layer to a depth of 50 meters throughout the area. A steep negative gradient was found below the surface layer to the shallow bottom over the continental shelf, and a relatively weak negative temperature gradient was found below the surface layer to the bottom over the continental slope. With the exception of the steep temperature gradient near the bottom at station 11, the pressure effect is dominant in determining the sound velocity. In Admiral Byrd Bay, sound velocity increased from the surface to the bottom, the maximum velocity of 4,882 ft./sec. occurring near the bottom. The rate of increase was similar to that found in the

upper 800 meters at station 12 in Atka Bay. The greater velocities present in the deeper water of Admiral Byrd Bay may be accounted for by the positive temperature gradient observed at these depths. There were no discernable sound channels for the 3 stations taken in the Weddell Sea.

V. MISCELLANEOUS

A. Ice Conditions

Ice conditions in the Antarctic areas covered during the present cruise were minutely observed and reported upon from the time ice was first entered in the Ross Sea on 12 January 1954 until the ATKA left the ice in the Weddell Sea on 20 February 1955. Quartermasters on watch, under the supervision of the Chief Quartermaster and the Navigator, made hourly ice observations from the bridge. These observations included ship's position, distance gained, input distance, number of forward turns of ship's propeller, and nature and thickness of the ice during the past hour. Observations reported on forms furnished by the Hydrographic Office and supplemented by some additional observations made by the civilian observer form the basis of the ice track charts (figs. 7 through 10) and the report on ice conditions.

The ATKA entered the ice ($70^{\circ}08'S$, $179^{\circ}30'W$.) on 12 January 1955 at 1400 LST (fig. 7). Surface water temperatures, which had been gradually decreasing since leaving New Zealand waters, commenced to drop more rapidly after passing $59^{\circ}S$, where the surface water temperature was $43^{\circ}F$. The Antarctic Convergence was passed between 62° and $63^{\circ}S$, and the surface water temperature dropped from 38° to $35^{\circ}F$. The first iceberg was sighted 6 miles off at 0930 LST on 12 January at approximately $69^{\circ}S$; icebergs had been noted on the radar screen during the previous night.

The first pack ice encountered was composed of scattered brash and rotten small floes and was of slight extent, open water being regained after less than an hour's run. Open water with only traces of ice, all rotten and easily transitted, continued until $72^{\circ}S$, where brash was encountered, followed by small floes. Ice concentration increased shortly thereafter and broken floes were passed through for several miles, followed by a stretch of scattered ice which continued until $73^{\circ}15'S$. Ice concentration increased to a maximum of 7/10 at $74^{\circ}S$. From $74^{\circ}S$ to approximately $76^{\circ}40'S$, where the open water of the Ross Sea was entered, scattered and broken ice was traversed. Stretches of open water occurred frequently, and occasional bergs, bergy bits, and growlers were present.

The Ross Ice Barrier was sighted at about $173^{\circ}W$ early in the morning of 14 January. From here to the former Bay of Whales, open water with occasional bergs was found. This condition existed eastward to about 45 miles beyond Little America. The break away of a large mass of shelf ice, sometime between 1948 and the present time, eliminated Discovery and Lindberg Inlets and the whole west side of the Bay of Whales, leaving an ice front of from 50 to 150 feet in



Figure 8. Ice Conditions Along Ship's Track - Cape Colbeck to Thurston Peninsula - January 1955.

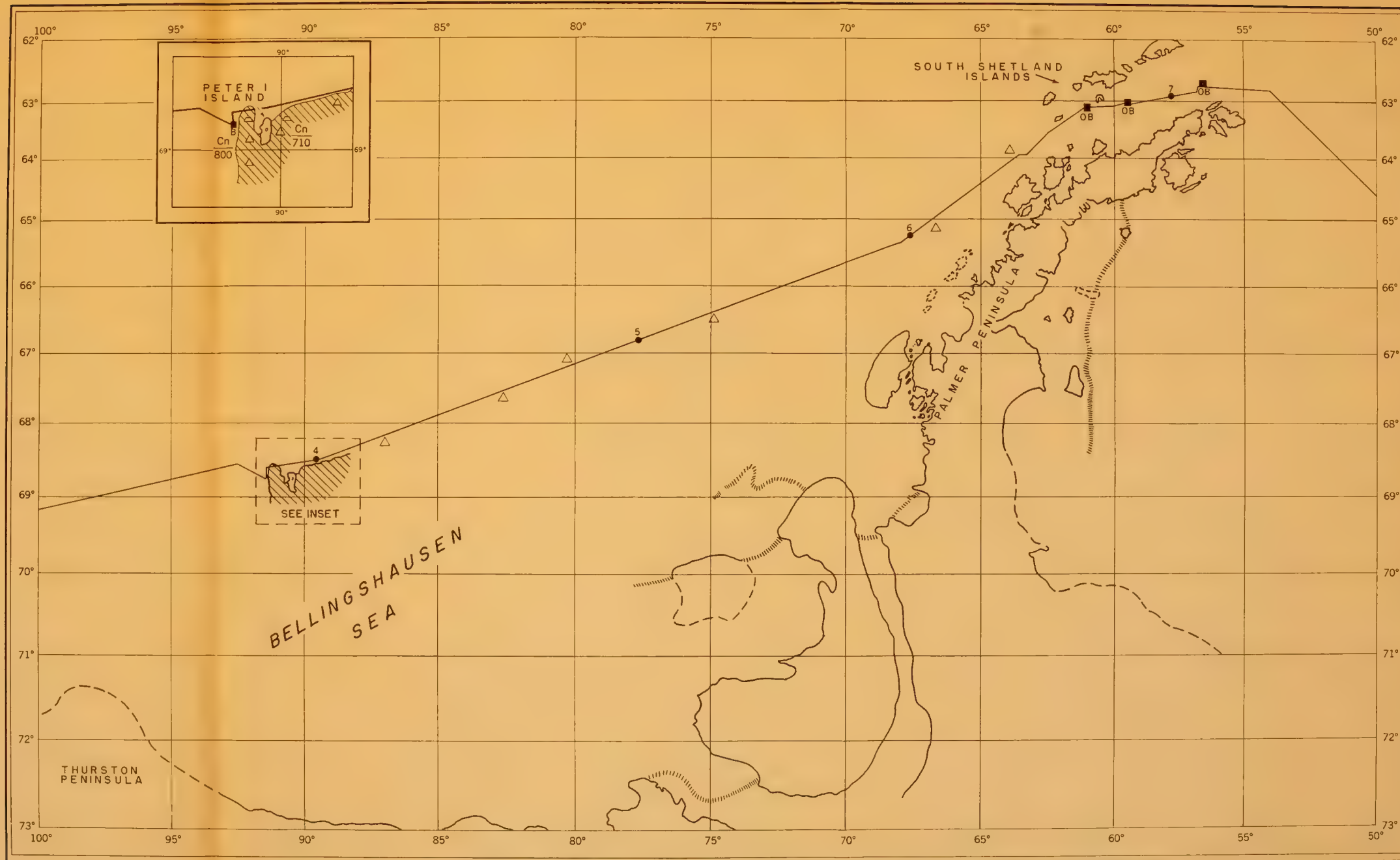


Figure 9. Ice Conditions Along Ship's Track -Thurston Peninsula Through Bransfield Strait - January-February 1955.

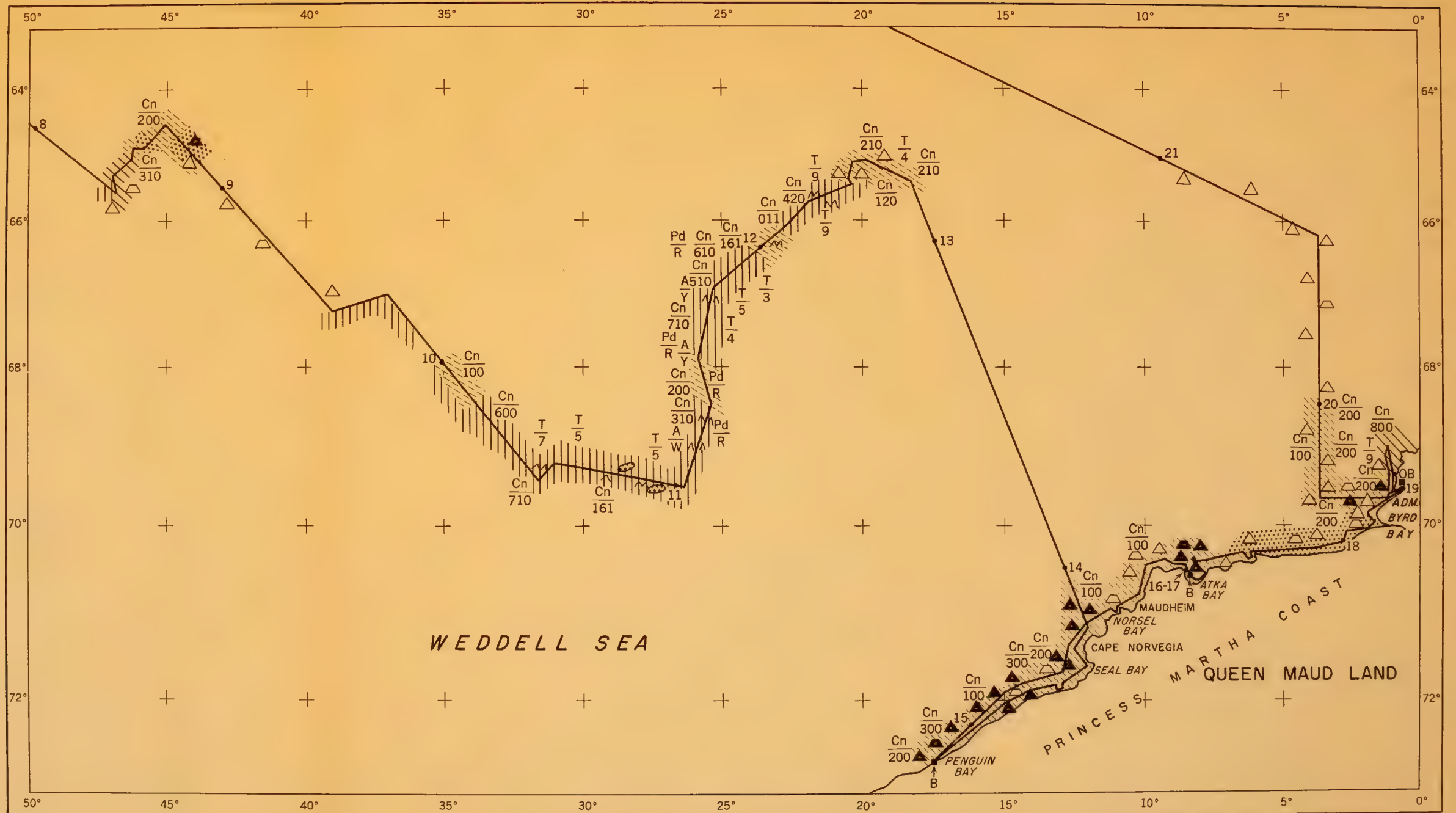


Figure 10. Ice Conditions Along Ship's Track - Weddell Sea Area - February 1955.

height with no fast ice and only shallow indentations. The southernmost penetrable limit for a ship was determined to be about $78^{\circ}31.6'$ S., in the former Bay of Whales area. A large crack opens from the sea into the shelf ice in the general direction of Roosevelt Island and apparently connects with an area of enclosed open water within. This may in the future cause a considerable change in the shelf ice front configuration, should a break occur at the crack, thus opening up the inner pool of water.

A scattered pack was encountered about 20 miles east of Kianan Bay, becoming close as the ship proceeded east. At the western approach to Okuma Bay, an area of close pack, impracticable to penetrate, was encountered. This pack, which was composed of 7-foot thick, hard floes, was circumvented by shifting course to the northwest and north along the 160th west meridian, and then heading southeast through broken pack to again attempt entry into the bay. Many icebergs, some grounded, blocked the entrance to Okuma Bay and extended in a closely assembled corridor along Edward VII Peninsula to Cape Colbeck. The shelf ice front continued along this area and appeared much the same as it did near the Bay of Whales. Off Cape Colbeck, icebergs became even more numerous and more closely associated; both tabular and pinnacled types were observed. Pancake ice was observed for the first time on the morning of 18 January. Open water was found along the Edward VII Peninsula from Okuma Bay to Cape Colbeck. Here, broken pack soon became close heavy ice 10 to 12 feet thick and made progress to the east impracticable, so a course was set to the north and northwest. During the night of 18 January, the ATKA remained motionless in the pack until 0800 LST on 19 January. On 19 January the ATKA was in continuous heavy pack which soon became consolidated; the pack was composed of medium floes 12 to 15 feet thick and numerous bergs were present in the pack. The heaviest pack encountered on the cruise was found in this area, approximately $76^{\circ}45'$ S. 159° W. When the ATKA finally extricated herself, it was discovered that one blade of the starboard screw had been broken off.

A more westerly course was pursued through close and broken pack to about $162^{\circ}30'$ W., where an almost due south course was set for Kainan Bay. Broken pack became scattered south of 77° S.; icebergs became more scarce and disappeared altogether. The water off the entrance to Kainan Bay, which had been open on 17 January, was now, 3 days later, filled with scattered and broken pack ice. This was traversed after some delay in locating a favorable path, and the ATKA tied up to the edge of the fast ice filling Kainan Bay at 2200 LST on 20 January. The fast ice of the bay was approximately 9.5 feet thick with 4 to 22 inches of snow cover.

After leaving Kainan Bay on 24 January, on a due north course, a short section of broken pack ice was traversed, followed by open water

as far as 77° S. Scattered ice from 3 to 5 feet in thickness, becoming broken with occasional bergy bits and growlers, was passed through on a northerly course along the $163^{\circ}35'$ W. meridian as far north as 76° S. Here, close pack prevented further northerly progress. On 25 January, the ship remained stationary in the pack waiting for it to open up. The course was shifted more to the westward and followed as far as 73° S. 170° W. Patches of broken and scattered ice and some open water were traversed. On 26 January open water was entered which continued until early on the 27th at $75^{\circ}20'$ S., where scattered ice was again encountered. The course was then shifted to the east and northeast through pack 10 feet thick, composed of medium and large floes. Occasional bergs had been sighted throughout the entire open water stretch commencing on 26 January. These became more numerous as an attempt was made at about 75° S. 153° W. to work south and penetrate the heavy ice guarding the entrance to Sulzberger Bay. One large iceberg over 6 miles long was passed in this area. At about 75° S., the attempt was given up and, in a blinding snow storm, the ship's heading was changed to the north to get out of rafted and hummocky ice, which was 10 to 15 feet thick and consolidated.

Approach to Sulzberger Bay from the north having thus been demonstrated to be impracticable within the limited time allowed, the ATKA headed northeast, skirting the heavy consolidated pack which existed at that time all along the northern approaches. The icebergs were left behind, and on the morning of 28 January (fig. 8) the ship found herself in broken pack with a noticeable swell which caused some rolling. Passing through areas of alternating broken and close ice on 28 and 29 January, the ship headed for Cruzen Island, where it was thought that an approach to Sulzberger Bay from the east along the coast might be possible. However, heavy rafted ice was encountered at approximately $73^{\circ}45'$ S. $145^{\circ}30'$ W., and the ship again turned north and east. On 28 January at about $144^{\circ}30'$ W., consolidated pack again prevented the ship from reaching the coast. At noon on 29 January, another attempt to head south for the coast was made at about 140° W., only to be frustrated by dense, rafted ice. Later on the 29th an unsuccessful attempt was made to head for Shepard Island at $72^{\circ}30'$ S., but heavy pack forced the ship back at about 2000 LST. On a northeast course, good progress was made through close pack 5 feet thick, which changed to more open ice about $71^{\circ}30'$ S. 131° W. and continued to 71° S. 127° W. Here, a determined attempt to force the ship through to Mt. Siple was made on 31 January. On the evening of 30 January at 71° S., the sun set for the first time since reaching Little America. At 0530 LST on the morning of 31 January, the ATKA was stopped by heavy, close, rafted, and hummocky pack, 12 to 15 feet thick and studded with numerous large bergs. Helicopters were sent out but soon returned reporting conditions unfavorable to the south. This happened to be one of the few bright, clear days experienced in the Antarctic. The ship had penetrated to within 50 miles of Mt. Siple but was forced to turn

about and head north and east through some rafted and hummocky ice to where scattered pack was reached at about 70° S. At 125°30' W., open water was reached and the ship headed southeast and later east, passing through stretches of scattered and broken pack 3 to 6 feet thick and, at about 120° W. through a short patch of close pack 9 feet thick. The heavier pack to the south was skirted by keeping to the north during the first and second days of February. During this period, the ATKA passed through open water with scattered pack ice to the south. A few small bergs were visible on the horizon. The open water was rather rough and there was some icing on the starboard quarterdeck.

On the afternoon of 2 February, the ATKA was making fair progress heading southeast through scattered and then broken pack of between 6 and 7 feet thickness, toward the Thurston Peninsula. When within 10 miles of the continental slope, a dispatch from CNO was received at 0130 LST on 3 February, ordering the ship to abandon efforts to reach the coast and proceed toward the Weddell Sea. This was the last attempt to break through the coastal icepack to reach the coast between Cape Colbeck and the Palmer Peninsula.

Broken pack followed by scattered ice and finally open water were passed through on 3 February as the ATKA headed northeast. Open water was entered at 69°50' S. 104° W. Numerous bergs were encountered between noon on 2 February and noon on 3 February. Then only occasional bergs were seen past Peter I Island through Bransfield Strait (fig. 9). Close pack protected the southern and eastern shores of Peter I Island and extended half way up the western side, but all the water from approximately 70° S. 104° W., to the Weddell Sea was open.

From Bransfield Strait, the ATKA proceeded on a general southeast course, sighting and entering ice at 2000 LST on 8 February at 65°30' S. 47°10' W. (fig. 10). A few bergs had been visible on the horizon during the day. Broken brash and block were soon encountered, and the pack became closed and heavier. Finally, the course was shifted to the northeast to skirt the heavier pack to the south. Following along the outer margin of the pack in the Weddell Sea, the ship passed through areas of close but not heavy pack, followed by scattered ice of 2/10 to 4/10 concentration. Upon turning again to the southeast, open water was entered just north of 65° S. From this point a southeasterly course, with only one jog to the northeast, kept the ATKA in open water as far as 68° S. 35° W. Here, light scattered pack was encountered, followed by a long stretch of open pack composed mainly of brash and block ice with some small floes between 5 and 7 feet in thickness. Some rafting was noted in this ice on 11 February, and the pack became generally thicker to the south. At 69°30' S. 26°20' W., the course was shifted to the north and a wide detour around the heavier ice was commenced, which took the ship back to nearly 65° S. 20° W. Although the pack was considerably heavier and closer to the south of this path,

the ATKA's course took her through open and scattered ice from 3 to 9 feet in thickness, with considerable rafting evident. Finally at about 0600 LST on 13 February, the ATKA reached open water which was fairly rough and caused considerable rolling. The course was shifted to the southeast (160° T.) on a direct line for Cape Norvegia. Open water continued until the cape was sighted at noon on 14 February. Along the coastal ice shelf front, the water contained scattered brash and block with numerous growlers and bergs from Cape Norvegia westward past Seal Bay and on into the Weddell Sea. The ATKA's farthest point of south and west penetration in this area was reached early on the morning of 15 February when a small bay was entered, with a limited amount of what appeared to be thin fast ice at its head. This bay was located at 72°42' S. 17°35' W. The ship then retraced its path to Cape Norvegia.

From Norsel Bay eastward along the Princess Martha Coast of Queen Maud Land, scattered brash and block with numerous bergs and growlers continued to Atka Bay and eastward to a large ice tongue extending out from the coast at the 0° meridian, between latitudes 69° and 70° S. Atka Bay was free of fast ice, and the ice front of the shelf ice was between 15 and 35 feet high. At the base of the ice tongue (provisionally named Observers Ice Tongue), a deep bay was entered but not surveyed. A bay some 15 miles farther to the north (later provisionally named Admiral Byrd Bay) was entered and the ship brought up to the fast ice at the head of the bay, some 4 miles from the entrance. Leaving Admiral Byrd Bay on the evening of 18 February, the ATKA steamed north along the ice tongue through scattered pack to a point just above 69° S. where close pack was encountered, which forced the ship to retrace her path to Admiral Byrd Bay.

Admiral Byrd Bay was entered again in the early morning of 19 February, and the ship was tied up at the edge of the fast ice at the head of the bay. Open water, with several bergs near the entrance, was found in the bay. The fast ice was estimated to be between 15 and 20 feet in thickness and appeared, from the accumulation of snow and névé, to be of considerable age. Slopes leading down to the fast ice from the surrounding shelf ice were covered with snow and névé, indicating that the fast ice had been in place for a long period of time. Leaving the bay on the evening of 19 February, a course was set almost due west through scattered pack with numerous bergs and growlers to near 4° W. Here, the ship headed due north and soon was out of the pack except for bergs and occasional block ice and growlers. The pack was left at approximately 68°30' S. 3°50' W. on 20 February and was never encountered again.

Near 66° S., the course was shifted to northwest and was followed in this general direction to the South Sandwich and South Georgia

Islands. Bergs frequently were passed and were in almost constant view on the radar screen throughout this passage, but it was not until South Georgia Island was approached that any great concentration was noted. Shortly after leaving South Georgia Island, a gigantic tabular berg over 42 miles in length by 10 miles in width with an almost continuous succession of water worn caves was passed. Dense fog encountered in this area prevented sighting of the numerous bergs which were evident on the radar screen for some distance north of this point.

The Antarctic Convergence was noted between $52^{\circ}00'$ and $57^{\circ}44'$ S. As anticipated, it was found considerably north of its Pacific position. Water temperatures gradually increased from 34° to 39° F. in the South Georgia area, dropped to 36° F. near the large berg, and then swiftly reached 44° F. at the Antarctic Convergence. With increase in water temperature, the fog gradually disappeared, the water became dark blue, and a spring-like atmosphere suddenly came into being. Temperature fluctuations encountered prior to crossing the convergence were caused by the near presence of land masses and icebergs.

Ice conditions encountered in the Antarctic areas traversed during the ATKA's cruise may be summarized generally as follows. In the Ross Sea, ice was rotten and easily penetrated but became increasingly harder in consistency as the ship proceeded eastward from Cape Colbeck to beyond the Thurston Peninsula. South of the ship's track in this area, ice appeared to be consolidated, thick, and difficult to penetrate as far toward the coast as observations could be made. In the Weddell Sea, ice consistency was unpredictable from the bridge; apparently hard ice was penetrated easily, while floes which appeared to be rotten, often brought the ship up with considerable impact. Ice to the south and west of the ship's track appeared to be consolidated for a considerable distance. Few polynyas were noted in the Ross Sea area and along the Antarctic Coast eastward; they became more frequent in the Weddell Sea area. Floes were, in general, snow covered throughout. Snow coverage ranged from a few inches to several feet. Pressure ridges and hummocky ice were infrequently seen, except in those areas where further penetration was considered impracticable. Bergs, often of large extent and mainly of the tabular type, were almost always present and in certain areas attained considerable concentration and close proximity. A limited amount of newly formed and pancake ice was encountered. Icing of the ship was noted on only a few occasions and then was very slight.

B. Bathythermograph Observations

The results of bathythermograph casts while underway and while in the pack ice are illustrated by the traces and profiles shown in figures 11 through 18. Two of the most interesting series of casts were made over the location of the Antarctic Convergence in the South Pacific and

South Atlantic Oceans. Vertical sections of water temperatures based on half-hourly BT observations across the convergence and horizontal plots of air temperature plus surface water temperature, salinity, and density obtained from bucket samples are presented for both the Pacific Antarctic Convergence and the Atlantic Antarctic Convergence. Typical BT traces are presented for other locations within the Antarctic operational area.

1. Antarctic Convergence

The position of the Antarctic Convergence is identified by a region of sudden increase in surface water temperature when proceeding away from the Antarctic Continent, the rapid change amounting to 2° or 3° F. over a very short distance. Also, surface water south of the convergence is characterized by lower salinity and slightly higher density than surface water found north of the convergence.

a. Pacific Antarctic Convergence--In the South Pacific the Antarctic Convergence was crossed enroute from New Zealand to the Ross Sea. The main convergence or zone of convergence occurred between 62° and 63° S. Surface water temperatures dropped from 41° to 38° F. approaching the convergence and from 38° to 35° F. at the convergence (fig. 11). Air temperatures were several degrees higher and exhibited a similar drop throughout the section. Lower salinities were not noted during the first drop in surface water temperature. The second drop in temperature was accompanied by a decrease in salinity, but a time lag of about 5 hours was noted before lower salinity values were obtained. The drop in salinity corresponded roughly with the occurrence of colder surface water or the point at which the rapid drop in temperature terminated. Density began to increase with the first noticeable drop in temperature. The slight rise in surface water temperature just before the drop has been noted in other sections taken across the convergence.

Figure 12 shows a vertical section of temperature across the Pacific Antarctic Convergence. The isotherms are drawn at intervals of 1° F. and are based upon temperatures recorded on the BT traces. The flow of colder Antarctic water under the warmer water to the north of the convergence is readily apparent if the 37° F. isotherm is taken as the boundary between the contrasting water masses. Approaching Antarctica, water temperatures of 32° F. or lower were not apparent on the BT traces until the zone of convergence was reached. The tongue of cold water, "winter water," advancing from the south is typical of such sections across the convergence. The wide gap in observations immediately south of the convergence occurred when the weather became too rough to permit taking BT casts.

b. Atlantic Antarctic Convergence--In the South Atlantic the Antarctic Convergence was crossed just northwest of South Georgia Island

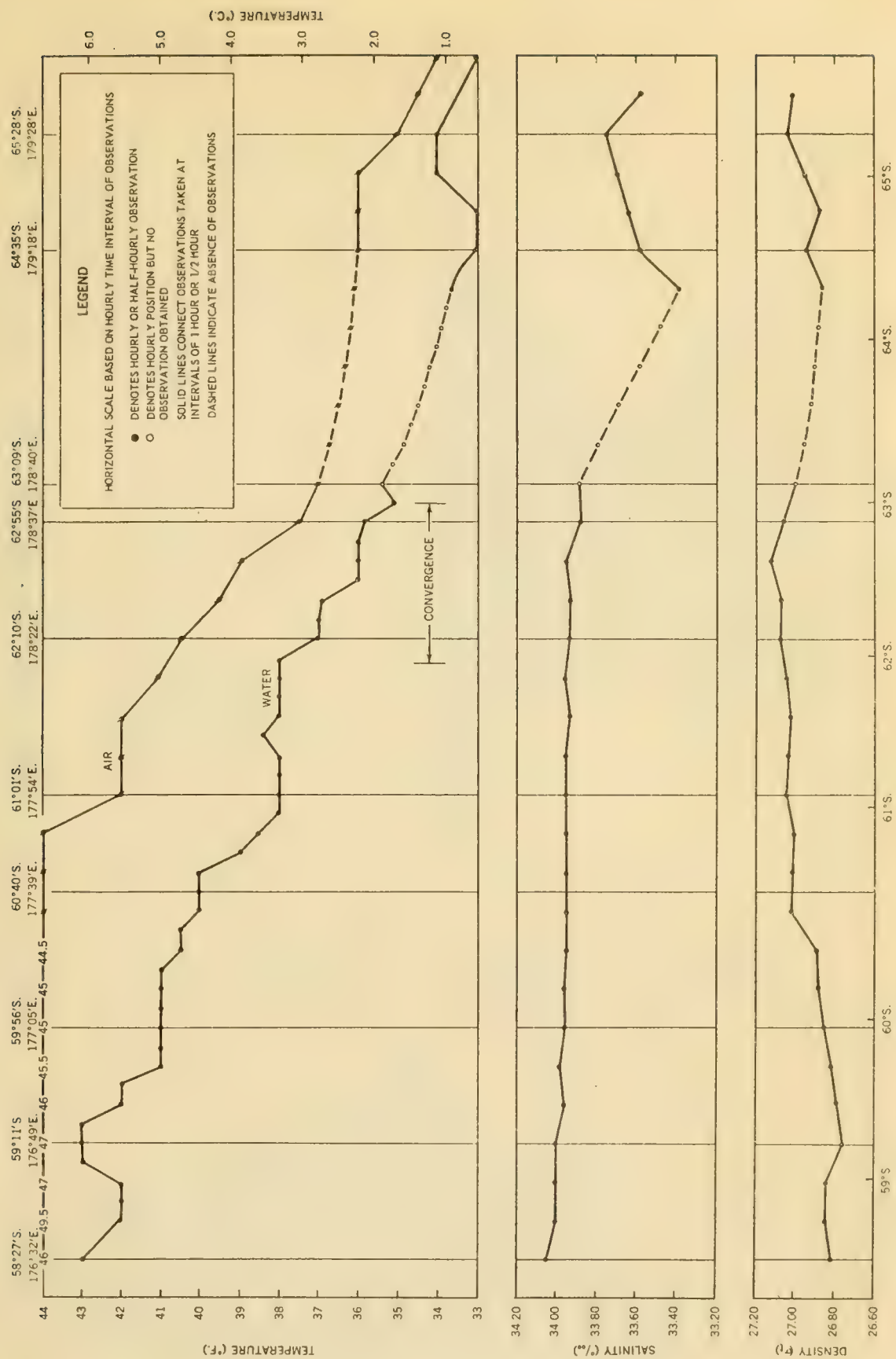


Figure 11. Horizontal Plot of Surface Observations Across Pacific Antarctic Convergence - January 1955.

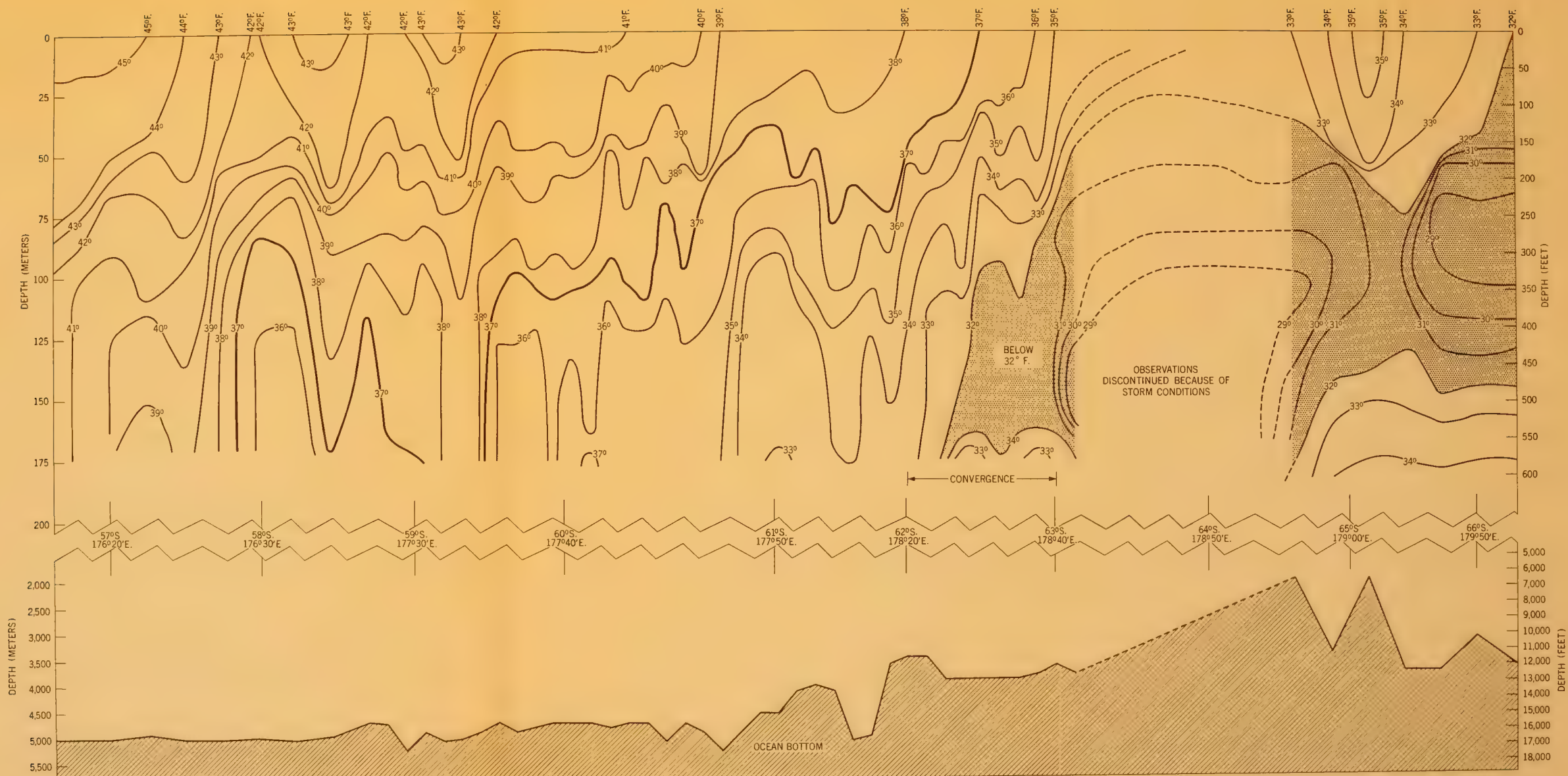


Figure 12. Vertical Temperature Section Across Pacific Antarctic Convergence - January 1955.

on 25 and 26 February 1955. As in the South Pacific, a similar double step in temperature rise was noted (fig. 13). The first rise of 36° to 44° F. occurred between $52^{\circ}30'$ and $51^{\circ}40'$ S. and the second rise of 45° to 53° F. between 49° and 48° S. Traveling north, salinity values and air temperatures began to rise preceeding the rapid rise in surface water temperatures. An iceberg 42 miles in length was passed at close range just prior to crossing the convergence. Melt water from this iceberg caused the sudden dip in salinity noted at about $53^{\circ}40'$ S. Surface water density decreased as lower latitudes were gained.

Figure 14 shows a vertical section of temperature across the Atlantic Antarctic Convergence. As shown in the vertical section across the Pacific Antarctic Convergence, the 37° F. isotherm serves well as a boundary between the contrasting water masses. Water temperatures below 32° F. are conspicuous near the surface layers for some distance north of the convergence and are absent south of the convergence.

c. Comparison of Pacific and Atlantic Antarctic Convergence-- The Antarctic Convergence is very strikingly portrayed in both the South Pacific and South Atlantic sections. Both sections show the rapid increase in surface water temperatures that mark the convergence, and the second step or rise in temperatures to the north of the convergence. Lower salinities occur in the colder surface waters immediately south of the convergence zones. Density gradually decreases to the north as warmer water is encountered in the surface layer. On the other hand, the Atlantic Antarctic Convergence is found farther north and is characterized by cells of colder water under the surface layer immediately north of the convergence. The cold water cells and the marked irregularity of the contours suggest the mixing of Antarctic Intermediate Water with deeper waters.

2. Ross Sea Area

Figure 15 shows bathythermograph traces for observations in the Ross Sea area during January 1955. Bathythermograph casts 124 and 162 were taken while underway in open water, hence the shallow depth of the trace; the others were taken while the ship was motionless. BT number 154 off Cape Colbeck, was taken while the ATKA was waiting for a shift in ice conditions to free herself from the consolidated ice in that area on 19 January. The water was almost isothermal to a depth of 900 feet at this point.

3. Cape Colbeck to the Bransfield Strait Area

Representative BT traces for the area east of Cape Colbeck during late January 1955 are presented in figure 16. Most of these casts were taken in water which was 2,000 fathoms deep or greater; number 213, off Peter I Island, was taken in only 1,200 fathoms of water and number 197

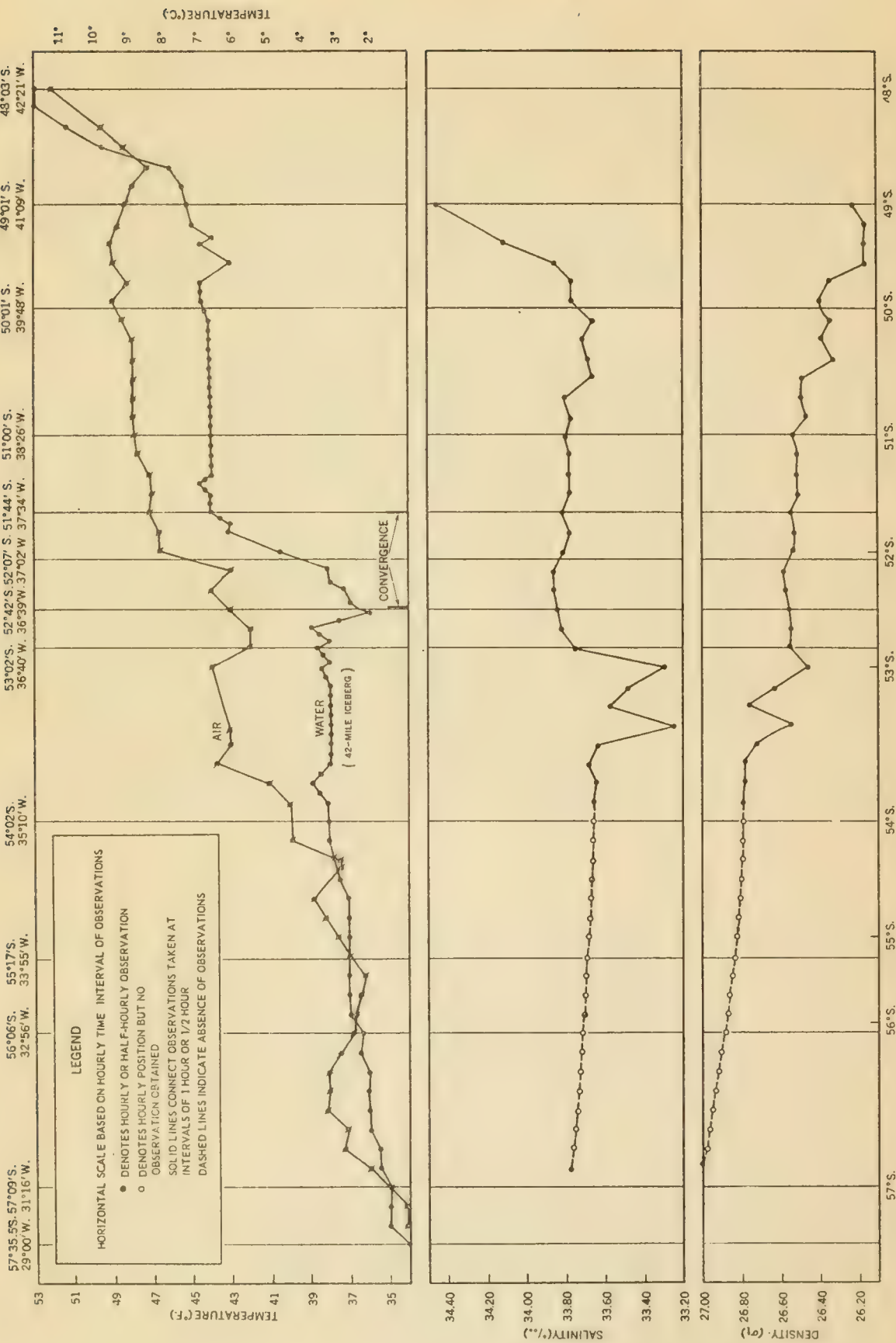


Figure 13. Horizontal Plot of Surface Observations Across Atlantic Antarctic Convergence - February 1955.

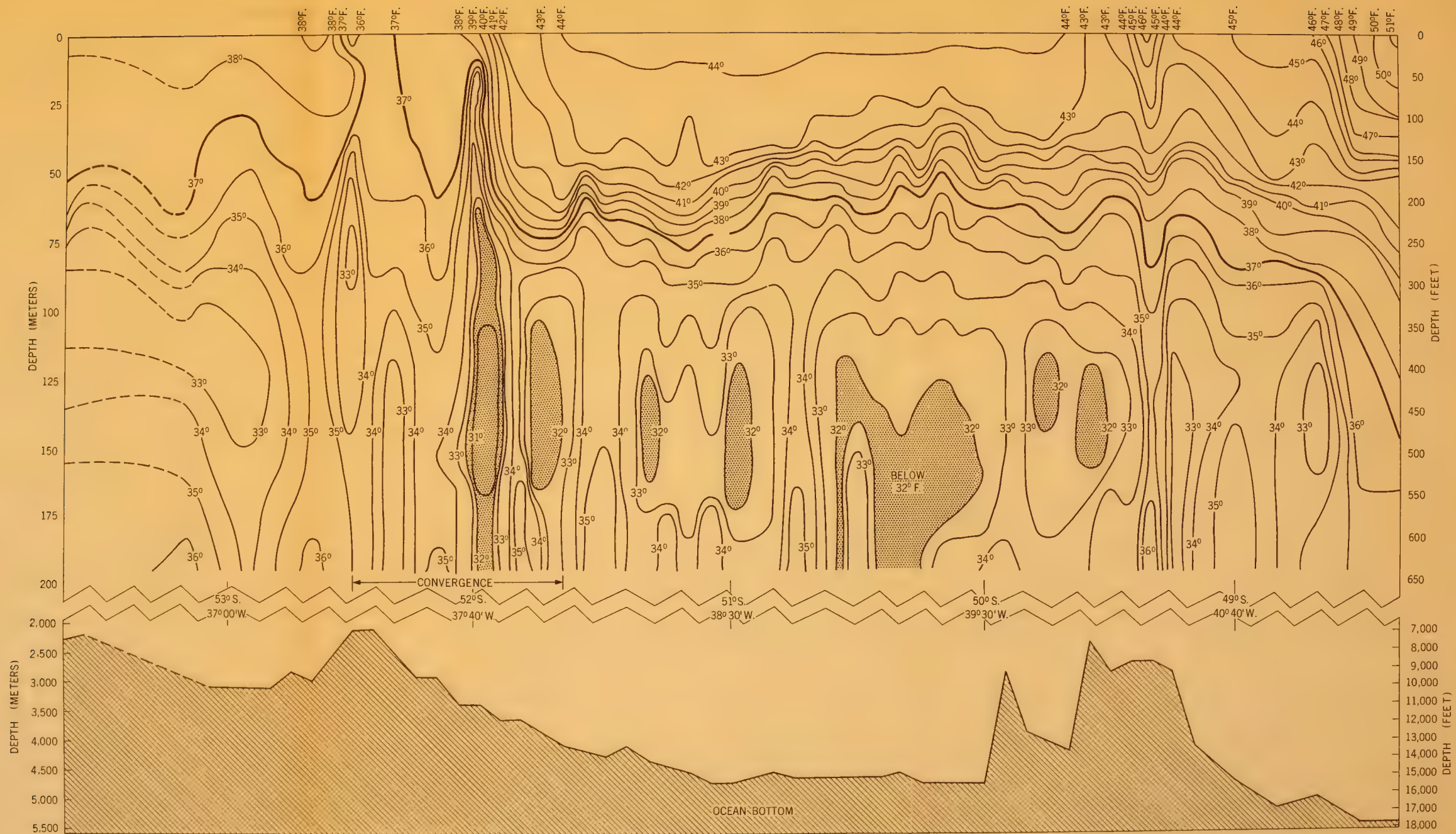


Figure 14. Vertical Temperature Section Across Atlantic Antarctic Convergence - February 1955.

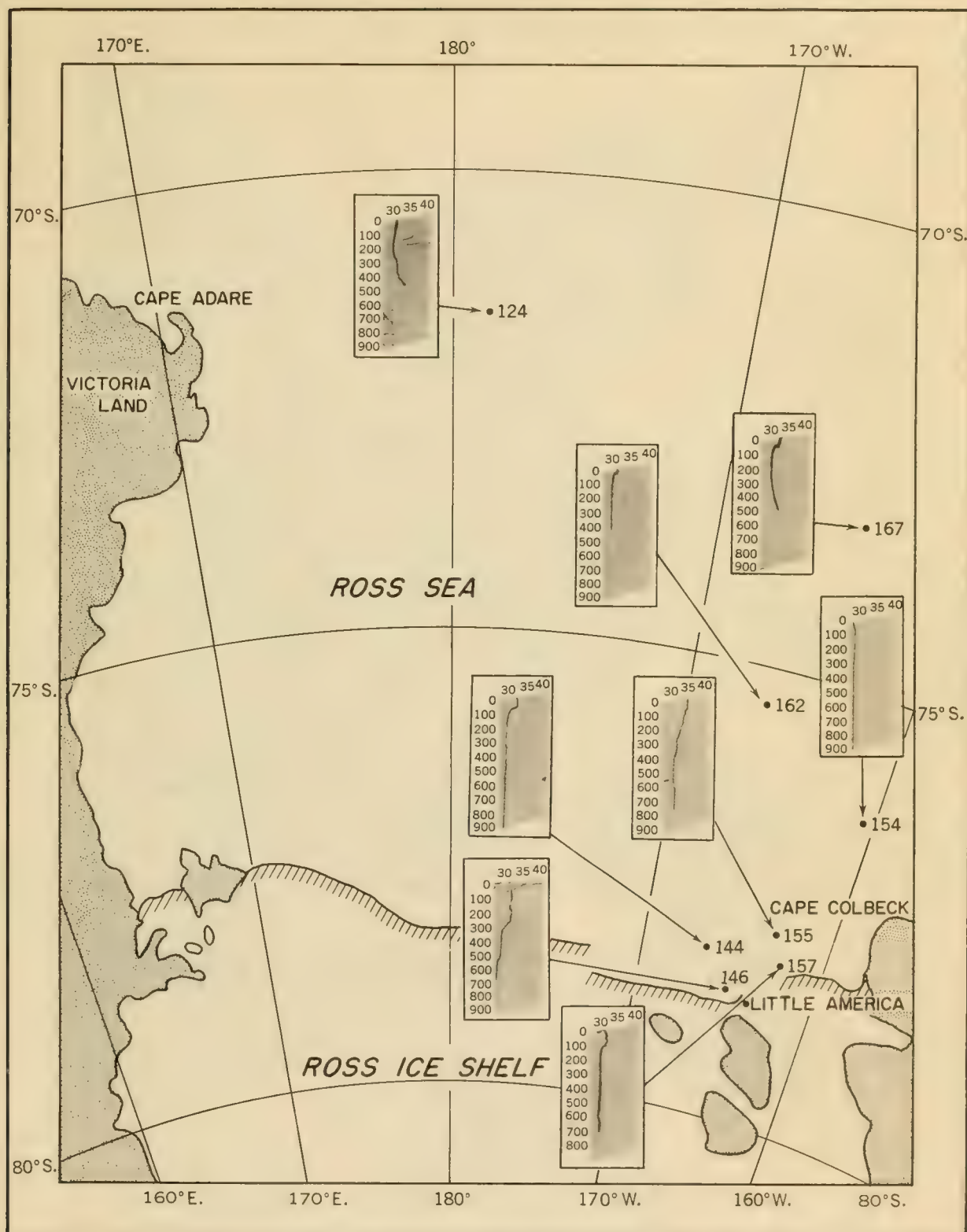


Figure 15. BT Traces - Ross Sea Area - January 1955.

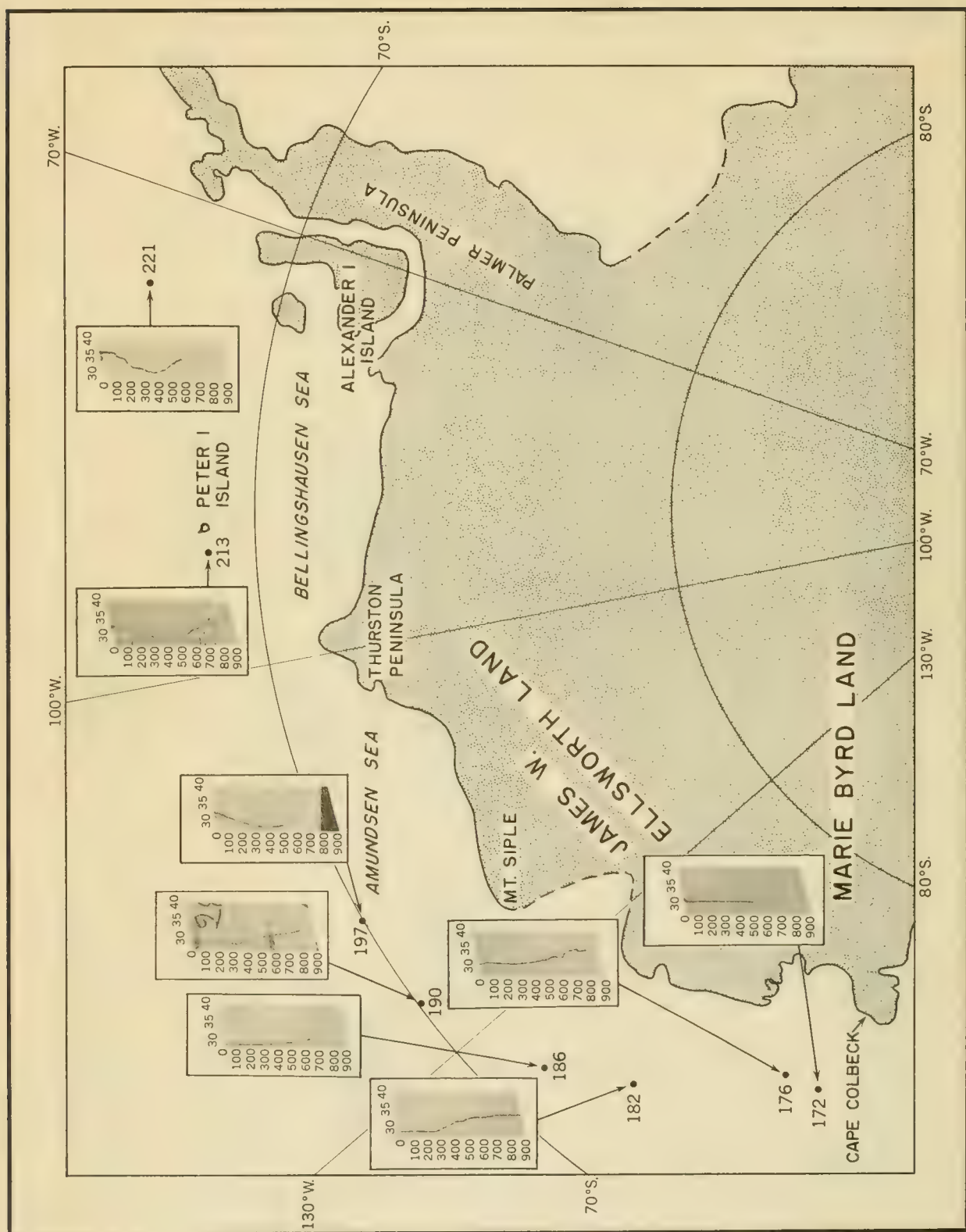


Figure 16. BT Traces - Cape Colbeck to Bransfield Strait Area - January-February 1955.

in the Amundsen Sea in 1,600 fathoms. From Cape Colbeck to the Amundsen Sea, colder water overlays somewhat warmer water; from there eastward through the Bellingshausen Sea the coldest water lies at a depth of about 400 feet.

4. Bransfield Strait

Figure 17 shows five BT traces for the Bransfield Strait area during early February 1955. The most westerly cast shows a thermal structure similar to that observed in the Bellingshausen Sea, the coldest water occurring between 200 and 400 feet depth. At the Deception Island station (BT slide 229) the influence of warmer water flowing south from Drake Passage is evident in the upper layers. This warm surface water is still in evidence at the mid-strait station (BT slide 230), but is no longer evident at the D'Urville Island station (BT slide 231).

5. Weddell Sea Area

Bathythermograph traces from casts taken in the Weddell Sea area during February 1955 are shown in figure 18. Since the ATKA's track followed along the edge of the pack ice, cooling of the surface layers (which is evident in slides numbered 244, 252, and 260) is probably caused by melting ice. Slide number 271 was taken in Penguin Bay at the edge of the fast bay ice. Upon leaving the Weddell Sea along a more easterly course, the traces become similar to those of the Bellingshausen Sea where the coldest water was found about 400 feet below the surface (traces 11, 20, 47, 48, 61 and 77).

6. Conclusions and Recommendations

Bathythermograph casts were made hourly throughout the cruise except when the ship was in ice where BT casts were made every 4 hours. The slides from these casts are on file at the Hydrographic Office and the data are available upon request. Routes followed enroute to and on the return voyage from the area of operations were selected to cover areas not hitherto travelled by ships equipped with BT's, so that a considerable amount of new data was accumulated, particularly off the eastern coast of South America.

Further expeditions would do well to repeat the observations across the Antarctic Convergence, particularly between longitudes 80° and 160° W. where no information exists. It would also be of considerable interest to run a line of closely spaced bathythermograph casts through Bransfield Strait in order to portray the complex thermal structure caused by inflow of warmer Drake Passage water and cold water from the Weddell Sea.

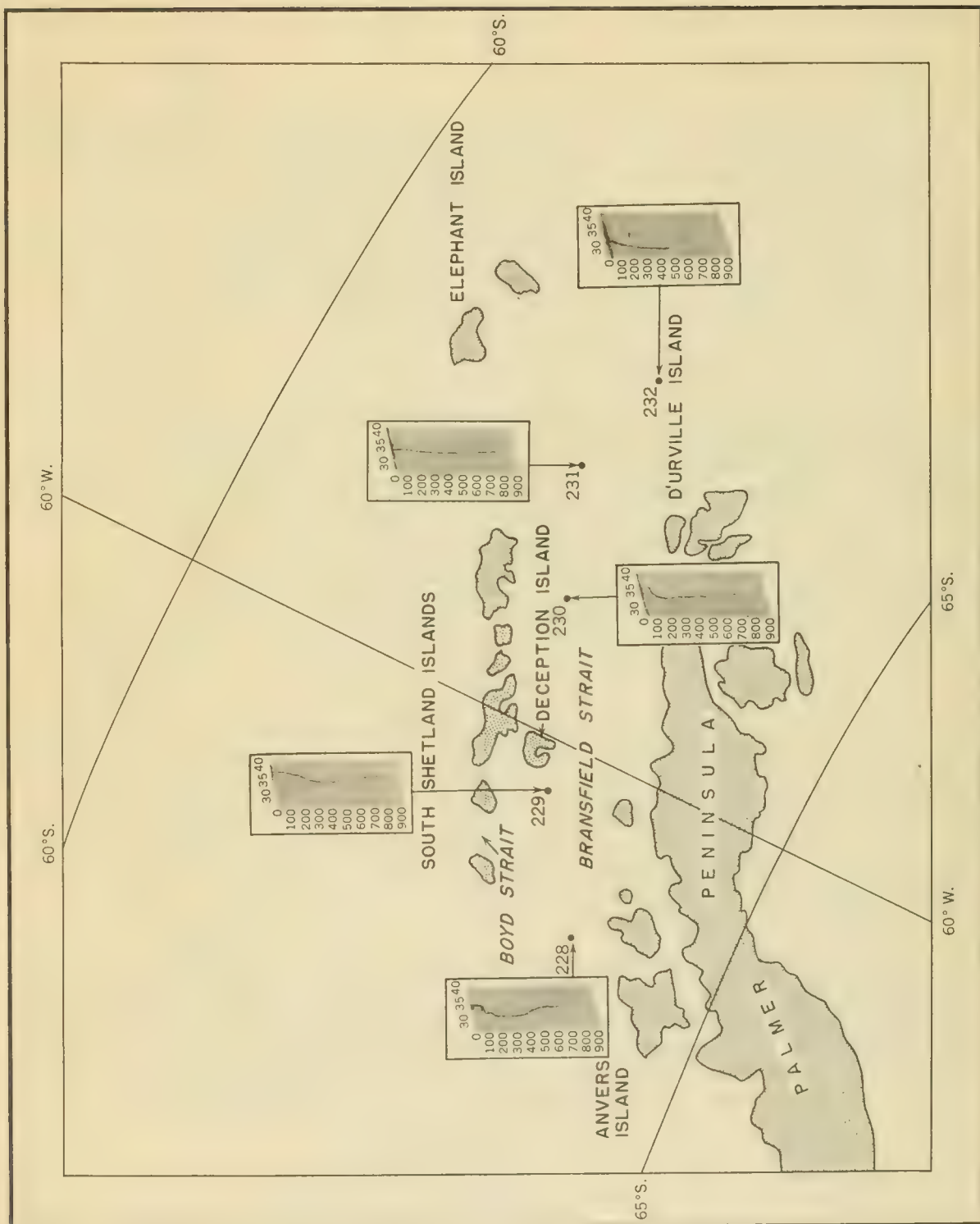


Figure 17. BT Traces - Bransfield Strait - February 1955.

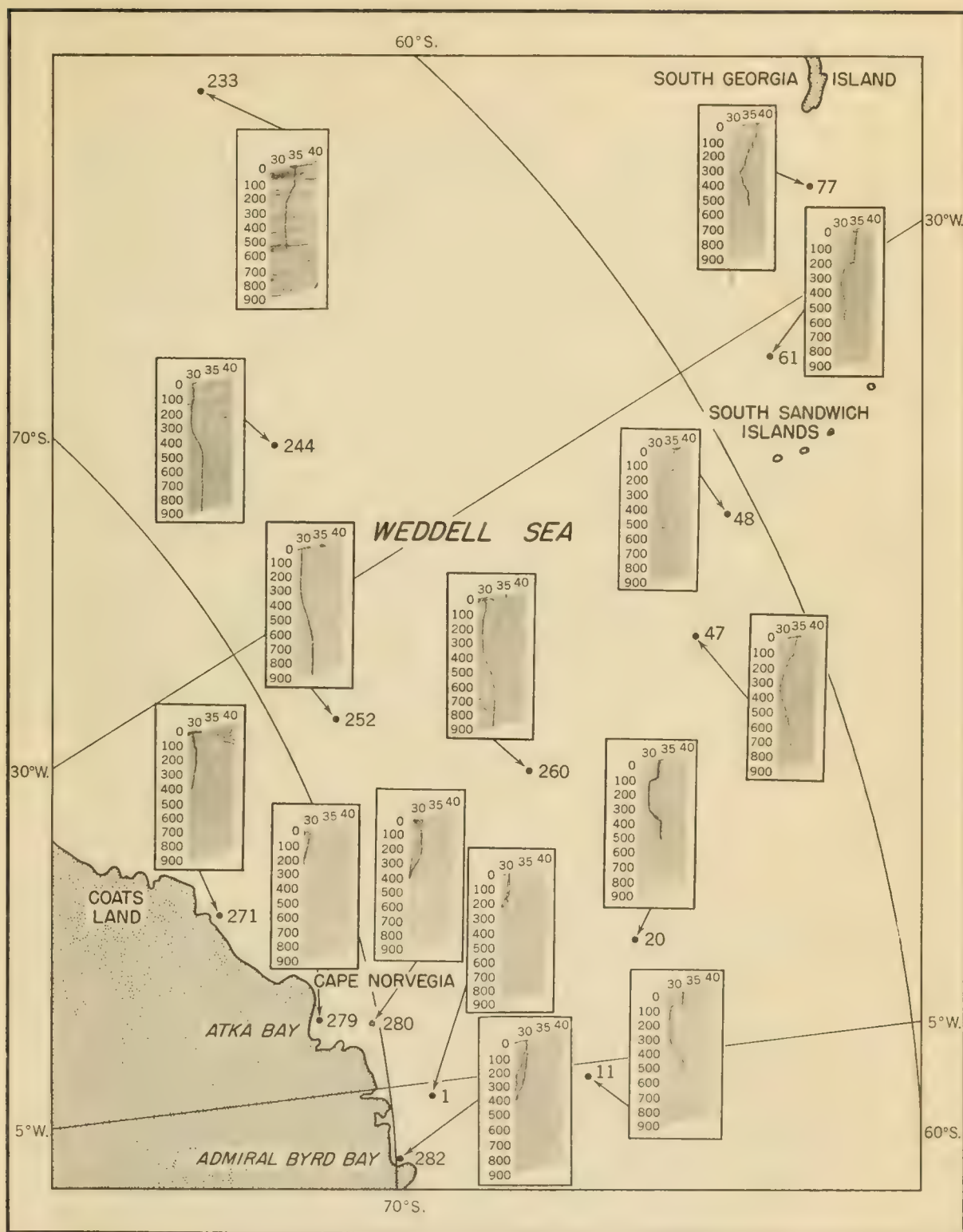


Figure 18. BT Traces - Weddell Sea Area - February 1955.

C. Meteorology

The period covering the ATKA's operations in the Antarctic area (12 January to 21 February) fell within the summer season when climatic conditions were most favorable. The Ross Sea, Cape Colbeck to Palmer Peninsula, and Weddell Sea areas showed a general seasonal trend in temperatures; the temperatures gradually decreasing until the lowest air temperatures were observed in the latter area. Temperatures were observed hourly at the weatherscreen which was located 44 feet above normal load line and which was obstructed by the bridge when the wind was from the starboard side. Temperatures taken with a sling psychrometer at the quarter deck level 15 feet above normal load line showed somewhat lower values when the wind was from the starboard side and over 20 knots velocity. Aerologists also made hourly temperature observations at the quarterdeck level, between 13 January and 14 February as a special accommodation, to obtain values more representative of the temperatures near the ice surface. Quarterdeck temperatures varied with the wind direction and velocity and showed values which were, at most, 2° F. lower than those observed at the weatherscreen.

The maximum temperature observed on the ship was 42° F., at Bransfield Strait; the minimum temperature observed on the ship was 7° F., at Atka Bay. Temperatures on the shelf ice were somewhat lower, the minimum observed being slightly below 0° F., at Atka Bay. Surface wind speeds showed a slight increase as the season progressed; the maximum wind speed observed in the Ross Sea area was 31 knots and in the other two areas 38 and 43 knots. The average daily maximum wind speed was 21.9 knots. The predominant wind direction in the Ross Sea area was east, in the area from Cape Colbeck to Palmer Peninsula southwest, and in the Weddell Sea south-southwest. Calms prevailed 4 percent of the time in the Ross Sea area and less than 1 percent of the time in the two other areas.

The first few days in the Antarctic were spent in the Little America area and were unusually clear and sunny, a condition which was rarely encountered during the remainder of the ATKA's stay in the operational area. The last day in the Antarctic, at Admiral Byrd Bay, also was bright and clear, but during the greater part of the Antarctic portion of the cruise, skies were overcast and the sun seldom seen. In all three areas low overcast skies were the dominant feature, occurring 74.3 percent of the time in the Ross Sea area, 53.6 percent in the Cape Colbeck to Palmer Peninsula area, and 54.3 percent in the Weddell Sea area. While at Kainan Bay, the sky to the north showed a very dark, stormy appearance during the 3 days the ship was tied up to the fast ice of the bay (see plate VIII). Veterans of previous expeditions stated that this sky was typical for the area during the summer, but to the newcomers it appeared as though a tremendous storm were about to occur any minute. On the shelf ice and fast ice of the bay, "white-out" conditions were common, especially in the Ross Sea area. Visibility

was generally good in all areas, being observed as 10 nautical miles or over 67 percent of the time in the Ross Sea area, 90.5 percent of the time in the Cape Colbeck to Palmer Peninsula area, and 72.5 percent of the time in the Weddell Sea area.

Rain or drizzle was not observed during the ATKA's stay in the Antarctic, but snow showers were reported 12 percent of the time in the Ross Sea area and 1.8 percent of the time in the Weddell Sea area; snow showers were not observed in the Cape Colbeck to Palmer Peninsula area. Snow was observed 23.6 percent of the time in the Ross Sea, 8 percent in the Cape Colbeck to Palmer Peninsula area, and 18.7 percent in the Weddell Sea area. Very little fog was noted in any of the areas, light fog being observed only 4.5 percent of the time in the Ross Sea and 1.2 percent in the Weddell Sea area. Fog was not observed in the intermediate area between Cape Colbeck and the Palmer Peninsula. The maximum observed barometric pressure occurred on 9 February in the upper Weddell Sea (996.0 millibars); the lowest barometric reading was made on 17 February at Atka Bay (971.8 millibars).

It will be noted from the above summary of weather conditions encountered during the ATKA's brief stay in the Antarctic, that opportunities for sun observations for periods of 24 hours or more are extremely limited, bright clear days being the exception. The high percentage of low overcast is largely responsible for this condition, plus frequent snow and snow showers. Visibility at sea level is good and fog is not a problem, but an unobscured view of the sun is a rare phenomenon during the summer months in the Ross Sea, Cape Colbeck to Palmer Peninsula, and Weddell Sea areas.

D. Bottom Sediments

1. General

There are three zones of bottom sediment types surrounding the Antarctic Continent, according to the most recent information. The deeper parts of the surrounding oceans (outer zone) have sediments of Globigerina ooze which intergrade with diatomaceous ooze in the intermediate zone as one nears the approaches to the continent. The innermost zone is a wide belt from 100 to 500 miles wide which extends out from the continental borders at least as far as the 3,500 meter line. The bottom sediments of the innermost zone are of terrigenous origin and are referred to as glacial marine deposits. The sediments in this zone have originated mainly from the adjoining land and have been carried to their present position by rafting ice and icebergs. Subsequent to their deposition, there has been little change in the physical or chemical characteristics of the sediments, or in their position.

Currents or waves have had little or no influence on their present distribution and as a consequence they show almost no sorting. Since the deposits now at the bottom of the cores were laid down, conditions seem to have changed somewhat. Considerable difference was found in many cases between the top and bottom of even such short cores as have been taken up to this time in the Antarctic. It is hoped that longer cores may be secured by future expeditions.

2. Ross Sea Area

The Ross Sea lies entirely within the glacial marine sediment belt, which in this area extends seaward to a depth of 3,500 meters or a distance of between 200 and almost 600 miles. Only a few scattered cores have been taken in the area but these show the uniformity of bottom conditions which persists over a large part of the area. Cores taken near shore in shallower water contain more sand and larger particles than those taken below a depth of 500 meters. Cores taken at over 3,500 meters are very similar to those in the central portion of the Ross Sea where depths are between 500 and 1,000 meters. On the present cruise, 12 cores were taken in the Ross Sea area by means of an 80-pound Phleger corer. These included 4 taken in a line running northwest from the Bay of Whales area, 3 off Kainan Bay, 1 at the entrance to Okuma Bay, and 4 which were taken along the edge of the Ross Ice Barrier from Little America to about 172° W. The characteristics of most of these cores were very similar. The cores ranged in length from 11 to 25 inches and averaged 17 inches. With one exception, namely the core taken on a hard bottom off Okuma Bay, penetration was good. The color of the sediments was uniformly dark yellowish brown, although the cores taken off Kainan Bay had a few streaks of greenish gray material. Sphericity of the mineral and rock fragments of sand size varied from low to moderate and was even high in a few instances. Roundness of particles ranged from angular to subrounded, but the great majority of the particles were decidedly angular. The surface texture of the mineral fragments and those of freshly broken grains was rough polished.

The type of sediment found is usually best described as glacial till with some sediments more closely resembling rock flour. Some samples were fossiliferous and all were without sorting to any appreciable extent. Pebbles were present in 5 of the 12 cores and were not included in the size analysis. The top and bottom of the cores showed a difference in amount of particles of sand size and larger, the top of all cores ranging from 1 to 38 percent with an average of only 7 percent, while the bottom of the cores varied between 9 and 59 percent with an average of 35 percent. A difference between top and bottom of the core also was noted in the clay sized fraction, the top ranging from 9 to 68 percent and averaging 55 percent, and the bottom ranging from 30 to 62 percent and averaging 41 percent.

The dominant mineral in these cores was quartz with some cores showing rock fragments as dominant. Rock fragments were composed of quartzite, granite, granitoid rocks, slate, schist, and gneiss. Secondary minerals were usually feldspar with some quartz, especially at the bottom of the cores. Other materials noted were mica, hornblende, and volcanic glass.

Organic remains were found mainly in the top portion of the cores, but in one core taken along the shelf ice edge at about 172° W. and in a core taken off Okuma Bay, organic remains were found at the bottom of the cores as well. The remains consisted of arenaceous and calcareous foraminifera, bryozoa, sponge spicules, diatoms, and radiolarians. A heavy liquid separation of heavy and light sand fractions and magnetic particles was carried out on the core taken along the Ross Ice Barrier at about 172° W. The light weight sand fraction was 92 percent, heavy weight sand fraction 8 percent, magnetic light weight fraction 0.4 percent, and heavy weight magnetic fraction 0.4 percent. It will be noted that magnetic sands are not abundant in this portion of the Ross Sea, although in other parts of the Antarctic a very high magnetic separation was obtained.

The median diameter of particles averaged 5.74 in ϕ units but was 1.38 ϕ at Okuma Bay entrance. Determination of sorting coefficients was possible only with the Okuma Bay core where it was found to be 4.00, a high figure denoting poor sorting. Although each core was carefully examined while in its plastic covering for both Beta and Gamma radiation, no evidence of radioactivity was noted in any core at any place tested. Samples of the bottom removed from the core liners were also tested without results. The Geiger counter showed a background of between 0.5 and 0.8 units. This count was lowered through absorption by the core to about 0.4 units.

Obtaining data on water content of the cores was not possible because they had dried out during the voyage home, hence there is no information available on the amount of compaction of bottom sediments. From visual inspection of the samples at the time they were taken, it is believed that the sediment is very loosely compacted. This fact, together with the large number of foraminifera present in the core, suggest a porous bottom sediment with a high water content which would absorb a considerable portion of sound waves.

Organic carbon (noncrystalline) content as determined by the Schollenberg method, averaged 0.46 percent in the top and bottom of the cores taken in the Ross Sea area. The largest percentage (0.91 percent) observed in the Ross Sea area occurred in the bottom portion of the core taken about 25 miles off Little America; the top percentage of this core was 0.38 percent. The minimum value noted in this area (0.23 percent) occurred at the top of the core taken at about 172° W.

along the shelf ice face. This core was one of two taken on the cruise which showed significantly greater amounts of organic carbon at the bottom of the core than at the top; the bottom percentage of this core was 0.37 percent.

3. Cape Colbeck to Bransfield Strait

The area from Cape Colbeck through the Amundsen and Bellingshausen Seas is not well known from the standpoint of bottom sediments. The continental shelf and slope to the 3,500 meter depth line varies from 50 to 275 miles in width. The few cores taken in this area by the ATKA were mainly on the shelf and in deeper water.

Two cores were taken off Cape Colbeck at distances of 3 and 60 miles in water which was 175 and 800 meters deep, respectively. The cores were 6 inches and 30 inches in length, and the color of the sediment was medium gray in the nearshore sample and dark greenish gray in the deeper core. Penetration was almost zero in the shallower core and excellent in the deeper. The latter core was the longest core obtained on the cruise. In the sand sized particles of the two cores sphericity varied from low to high; roundness varied from angular to subrounded in the nearshore core and was subrounded at the bottom of the deeper core. Surface texture of the particles was rough polished, dull, and smooth. In the core taken 3 miles off Cape Colbeck, the sediment was marine glacial till. In the core obtained 60 miles off the cape, in 800 meters of water, the sediment type was a rock flour.

Particles of sand size or larger made up 88 percent of the shallower sample and 5 percent of the deeper sample. Clay size particles made up about 3 percent of the shallow core and 52 percent of the deeper core. The dominant mineral in the deep core was quartz with feldspar secondary. Slate, schist, and graywacke were present in the top and slate, schist, volcanics, and graywacke in the bottom of the deep core. Quartz also was the dominant mineral in the shallow core with feldspar secondary except for rock fragments found at the bottom of the core. The rock fragments were composed of quartzite, slate, granite, granitoid rocks, schist, gneiss, sandstone, and graywacke. The only organic remains found in the cores consisted of some chitin at the top and diatoms at the bottom of the shallow core, and some arenaceous foraminifera at the top of the deep core. The sorting coefficient for the shallower core was 2.69 at the top and 4.80 at the bottom, skewness in ϕ units was -0.08 and -0.45, and median diameters in ϕ units were 1.05 and 0.38, respectively. The organic carbon content was very low in the shallow core (0.12 percent at the top and 0.02 percent at the bottom), possibly because of the large percentage of sand sized particles. The organic carbon content in the deeper core averaged 0.37 percent.

Cores taken in the Amundsen Sea and the Bellingshausen Sea at depths of 1,840 and 1,950 meters, showed marked contrasts in their sediments. The core taken off Peter I Island in the Bellingshausen Sea was at the edge of the continental shelf, which sweeps out from the coast to include the island. The core taken off Mt. Siple in Amundsen Sea was on the slopes of an uncharted seamount, which rose from a depth of 6,500 meters. No penetration was obtained in the Mt. Siple core, and only 11 inches of core was obtained at Peter I Island. At Mt. Siple, the corer hit bottom with a bounce, and only a small sample of coarse sand and gravel with some silt was retained within the core catcher. The sphericity of these particles was moderately high to high, the roundness ranged from subrounded to very angular, and the surface texture was rough dull, smooth, or pitted. Globigerina was the predominant sediment type found and volcanic sand the secondary type. Feldspar also was noted. The only organic remains consisted of some calcareous foraminifera. The core taken off Peter I Island was very similar from top to bottom. The sediment color was grayish brown, sphericity varied from low to high, roundness of the particles ranged from subangular to very angular at the top and rounded to very angular at the bottom of the core. Surface texture was rough polished on mineral grains and some volcanic glass fragments, but was dull smooth on other particles. An average of 18 percent of the particles in the core were of sand size or larger, coarse silt made up 60 percent of the sample at the top of the core and 49 percent of the sample at the bottom of the core. Clay sized particles made up only 11 and 17 percent of the samples at the top and bottom of the core. The sorting coefficient was 1.67 at the top and 2.00 at the bottom of the core; skewness in ϕ units was -0.10 and 0.00, and the median diameter of particles in ϕ units was 5.37 and 5.28, respectively. Volcanic glass was the dominant mineral, quartz was secondary and feldspar was also present. Organic remains consisted of arenaceous and calcareous foraminifera, sponge spicules, diatoms, and radiolaria. A heavy liquid separation showed the following percentages at the bottom of the core; light weight sand fraction 60, heavy sand fraction 40, magnetic light sand fraction 0.9, and magnetic heavy sand fraction 7. The quantity of heavy magnetic particles was unusually high. In other regions, where comparisons have been made, such high quantities are usually associated with local magnetic anomalies. Organic carbon in the Peter I Island core averaged 0.34 percent.

4. Bransfield Strait

Bransfield Strait lies on the continental shelf which extends from 75 to over 100 miles north of the South Shetland Islands, which form the northern shores of the strait. Three cores were taken, one at each of the oceanographic stations occupied; namely, west of Deception Island, in the middle of the strait, and north of D'Urville Island. The sediments showed a decided increase of particle size toward the east.

Sediment types also changed from rock flour at the western station to glacial till at the bottom of the midstrait core and throughout the short core obtained off D'Urville Island, the cores being taken in 590, 840, and 225 meters of water, respectively. Penetration was good except at the D'Urville Island station where only 6 inches of sediment was obtained; the other two cores were 24 inches in length. Color of the sediment ranged from light olive gray in the two western stations to olive gray at D'Urville Island. Sphericity of particles was low moderate to high, roundness was decidedly angular with particles at the bottom being very angular in all cores. Surface texture of particles was mainly rough polished in the mineral grains and smooth and dull in the rock fragments. At the bottom of the Deception Island core and at the top of the midstrait sample the particles were pitted.

Particles of sand size or larger showed a decided increase eastward, being on an average 4 percent of the sample at Deception Island, 14 percent at the midstrait core, and 51 percent off D'Urville Island. Clay sized particles were 38 percent, 41 percent, and 21 percent at the three stations from west to east. The dominant material at the top of the Deception Island core was volcanic glass, diatoms were dominant at the bottom of the core. The dominant material at the top of the midstrait core was volcanic ash, scoria was dominant at the bottom. Volcanic ash was again dominant off D'Urville Island. Secondary minerals at top and bottom were noted as follows: at Deception Island, diatoms and quartz; midstrait, quartz and diatoms; and at D'Urville Island, quartz. Feldspar, quartz, diatoms, and volcanic ash were also noted at locations where they were not dominant or secondary, while at the bottom of the midstrait core there were some acid minerals noted, although in small amounts. Sponge spicules and diatoms were found at the top of the midstrait and D'Urville cores and the bottom of all three cores. Arenaceous foraminifera were found at the top of the Deception Island core and the bottom of the midstrait core. Calcareous foraminifera were present in both the top and bottom of the core at Deception Island and at the top of the midstrait core. Radiolarians were found only at the top of the cores taken at the two western stations. A heavy liquid separation made on the bottom sample of the Deception Island core gave the following results; light weight sand fraction 66 percent; heavy sand fraction 34 percent; magnetic light sand fraction 4 percent; and magnetic heavy sand fraction 8 percent. Here, as at Peter I Island, the magnetic separation figures are very high. The median diameter of the particles in ϕ units in the top sections of cores was as follows; Deception Island 6.82, mid-strait 6.55, and D'Urville Island 3.90. The median diameter at the bottom of the two western cores was 6.78 and 7.10.

Organic carbon content was higher in the Bransfield Strait sediments than in any of the other areas investigated on the cruise, averaging

0.88 percent in the three cores. It was highest in the midstrait core, where a maximum of 1.24 percent was noted at the top of the core. The core taken off Deception Island averaged 0.80 percent while only 0.47 percent was noted at the core taken off D'Urville Island. The high organic carbon content of cores taken in this area is probably caused by the large diatom population and incoming organic matter flowing through the strait.

5. Weddell Sea Area

Along the Princess Martha Coast of Queen Maud Land, the continental shelf is much narrower than on the Pacific side of the Antarctic Continent and rarely exceeds 100 miles in breadth. In places it is as narrow as 30 to 40 miles wide and the continental slope is steep beyond. All cores taken in this area by the ATKA were on the continental shelf or, in one case off Atka Bay, at the start of the continental slope.

Five cores or bottom samples were taken along the Princess Martha Coast during the ATKA Cruise. At Penguin Bay the corer hit hard on the bottom at 237 meters depth, and a small sample of green gray coarse sand and silt was obtained. In Atka Bay, one core and one snapper sample were obtained at depths of 156 and 68 meters, respectively. The core was 11 inches in length and indicated a shallow covering of sediment over a hard rocky bottom. The fact that the corer hit with a distinct impact and large numbers of hydroids, requiring a hard substratum for attachment, were obtained in the snapper sample indicated a rocky bottom. The upper 6 inches of the core was composed of dark yellowish brown sediment, while the bottom 5 inches was grayish olive. Sand sized particles or larger comprised 55 percent of the total sediment. The sphericity of the particles varied from low to low moderate; roundness varied from very angular to subangular; surface texture was rough dull in the rock fragments, and rough polished in the mineral grains. Clay sized particles averaged 19 percent of the total sediment. Besides hydroids and calcareous algae, the sample contained sponge spicules, arenaceous and calcareous foraminifera, bryozoa, radiolaria, and ostracods. This was the only bottom sample collected which contained Ostracoda. Bryozoan remains were dominant at the top of the core and pelagic tests of various sorts at the bottom. Sponge spicules were secondary at the top and bottom. Quartz and rock fragments were also noted. The snapper sample obtained a number of bryozoans and coarse sand. Two attempts at taking a core about 10 miles seaward from Atka Bay resulted in hard hits on both tries in 823 meters; a little sand and some bryozoans were obtained. Organic carbon content in the 10-inch core taken at Atka Bay averaged 0.37 percent and showed considerable difference between the top and bottom content of the core. An average of three analyses for the top of the core showed a carbon content of 0.45 percent; the bottom content was only 0.22 percent.

At Admiral Byrd Bay a bottom core 11 inches in length was obtained at the edge of the bay fast ice in 2,300 meters of water. The corer could be felt hitting the bottom even at that depth and it is concluded therefore that conditions were similar to those found at Atka Bay, where there was a hard bottom covered with a thin layer of sediment. At Admiral Byrd Bay, the entire core was colored light olive gray; sphericity varied from low to low moderate at the top, low to high in the center of the core, and low to high moderate at the bottom. In degree of roundness the particles were angular to very angular at the top and bottom, and rounded to very angular in the center of the core. At the top of the core, surface texture of the particles was rough and polished or striated and smooth; in the center it was dull and rough or polished and striated, and at the bottom of the core the particles were polished and rough. The sediment type at the top and bottom of the Admiral Byrd Bay core was fine glacial till and in the center it might be called well sorted re-worked glacial till.

The percentage of sand sized particles and those of larger size was 35 and 42 at the top and bottom of the core respectively, while in the center of the core the percentage reached the high figure of 94 percent. Clay sized particles were 25 percent of the total of the top and bottom, and only 5 percent in the center of the core. Sorting in the center of the core was 1.20, which was by far the best sorting coefficient observed in the Antarctic on this cruise; sorting at the top was 4.29 and at the bottom 6.41. The amount of skewness in ϕ units was 0.37 at the top of the core, 0.30 at the center, and 0.59 at the bottom. Median diameters in ϕ units were as follows: top, 5.03; center, 1.25; and bottom, 4.75.

At the top of the core the dominant material was arenaceous foraminifera with quartz secondary and feldspar also present. In the center and at the bottom of the core, quartz was dominant, feldspar secondary, and there were some rock fragments present. Rock fragments consisted of granite, schist, and gneiss. There was a great abundance of arenaceous foraminifera at the top of the core, plus some sponge spicules, diatoms, and radiolarian tests. In the center of the core only one test of an arenaceous foraminifera was observed, while at the bottom arenaceous foraminifera, sponge spicules, and radiolaria were noted. A heavy liquid separation made of the bottom portion of the core showed the light weight sand fraction to be about 75 percent of the total sediment, heavy weight sand fraction 25 percent, light magnetic sand fraction 0.2 percent, and heavy magnetic sand fraction 2.0 percent. Organic carbon content in the Admiral Byrd Bay core was low. This was one of the two cores taken on the cruise which showed higher organic carbon at the bottom of the core than at the top. The core as a whole averaged only 0.17 percent, with the center showing a very small amount (0.01 percent), the top 0.19 percent, and the bottom 0.30 percent.

It will be noted from the above description of the characteristics of the sediment contained in this short core, that conditions were markedly different at the time when the center portion of the core was being deposited than at either the present time or earlier. It would be interesting to speculate upon how long ago conditions occurred which permitted such excellent sorting as was observed in the particles deposited in the midportion of the core taken at Admiral Byrd Bay. Such conditions would have involved retreat of the ice shelf sufficiently so that water runoff from the bare land occurred, or the existence of a strong submarine current having the same power of causing well sorted sediments after their deposition.

6. Conclusions

It is evident from the descriptions of cores taken in the Ross Sea area and in the Weddell Sea area, that there are marked differences in the two areas. The continental shelf is much narrower on the Atlantic side of the Antarctic Continent, the layer of sediment appears to be much thinner, and the substratum harder. The sediments are of a more grayish color on this side, but tend toward the yellow-brown shade observed on the Pacific side. The only place where any degree of sorting was observed was at Admiral Byrd Bay on the Atlantic side. Magnetic grains were most evident in the Bellingshausen Sea and Bransfield Strait; however, they were not abundant in the Antarctic area as present inadequate sampling indicates. Radioactivity appears to be nonexistent if the few tests that were made on cores can be used as a criterion in the areas investigated.

In general, organic carbon was low. This is especially notable when one considers the amounts reported from shelf areas in lower latitudes, where organic carbon usually runs between 2 and 3 percent and may, under special environmental conditions, reach as high as 6 to 10 percent. The Gulf of Mexico averages about 2 percent. When one compares these figures with averages obtained in the Ross Sea (0.46 percent), Peter I Island (0.34 percent), Atka Bay (0.37 percent), and Admiral Byrd Bay (0.17 percent), it is apparent that Antarctic bottom sediments are low in organic carbon. This agrees well with some studies of organic carbon made in the Arctic where consistent figures of less than 1 percent were reported. Bransfield Strait showed the highest percentages of organic carbon, largely because of the greater supply from pelagic diatoms which were most numerous here. There can be little terrigenous source of organic matter in the Antarctic, and most or all organic matter must come from organisms of the sea. Low temperatures aid in retaining organic matter in the bottom sediments but it appears doubtful if variations in oxygen content can have much effect.

E. Transparency and Plankton

Transparency of the surface waters was determined at all oceanographic stations where light intensity permitted, and at other locations whenever possible. A white Secchi disc, 30 centimeters in diameter, was used in making these determinations, all the observations being made by the oceanographer to minimize personal error in observations. In general, the transparency of surface water closely followed the abundance of plankton or detritus in the water. Although plankton tows were not a part of the regular oceanographic program, vertical or oblique hauls with a half-meter net at depths of 25 to 50 meters were made whenever possible as a matter of interest.

In the Little America area, transparency of the surface waters ranged from 5 to 7 meters, and was correlated with a moderately heavy plankton concentration, also much detritus. Off Cape Colbeck, transparency reached 19 meters in the icepack where it was impracticable to make a plankton tow. In the Amundsen Sea off Mt. Siple, where no plant plankton or detritus were visible in the collection, a transparency of 23 meters was obtained. Farther to the eastward, off Peter I Island, transparency was reduced to a low of 5 meters; a plankton tow revealed an extremely heavy concentration of greenish colored plankton composed of diatoms and many copepods. In this area, and in the Ross Sea area, considerable concern was felt by the ship's engineer over faulty operation of the evaporators which became plugged with a heavy coating inside, making frequent cleaning necessary and greatly impairing the ship's capacity for making fresh water. This trouble quickly cleared up upon entering clearer waters having less plankton. In Bransfield Strait transparency ranged from 11 to 12 meters, and plankton tows collected only moderately concentrated plankton except at the station off D'Urville Island where diatoms were very abundant. In Atka and Admiral Byrd Bays transparency was 13 meters. Moderate amounts of plankton were present in Atka Bay. A plankton sample was not obtained in Admiral Byrd Bay because both nets were lost.

The greatest transparency reading obtained during the cruise was at 72°38' S. 17°39' W. along the Princess Martha Coast, Queen Maud Land. Here, at the head of a little bay (Penguin Bay) in the shelf ice of the Weddell Sea, a transparency of 27 meters was observed along a narrow fringe of fast ice. A plankton tow was not obtained.

Dr. Thomas E. Bowman of the Smithsonian Institution, U. S. National Museum, identified many of the dominant forms of plankton obtained. Dr. Harold A. Rehder identified the pteropods. The composition of the tows showed no new forms, all forms having been previously reported from the Antarctic regions. Off Little America there was much detritus, but no plankton. A tow taken west of Little America contained the

copepods Ctenocalanus vanus, Oithona similis, and a species of Corycaeus also, euphausiid larvae, amphipods, polychaetes, pteropods (Limacina helicina), and siphonophores. Off Mt. Siple the copepods Calanoides acutus and Calanus propinquus, the euphausiid Thysanoessa macrura, and some appendicularians and pteropods (Limacina helicina) were obtained. Off Peter I Island, the tow contained large numbers of Calanoides acutus and Oithona similis, plus euphausiid juveniles and pteropods (Limacina helicina). A tow taken off Deception Island contained large numbers of the copepods Oithona similis and Ctenocalanus vanus, plus Calanoides acutus, Calanus propinquus, the hyperiid amphipod Parathemisto gaudichaudi, and euphausiid juveniles. In the center of Bransfield Strait a plankton tow contained moderate numbers of Oithona similis and Ctenocalanus vanus, a species of Calanus (possibly C. propinquus), the euphausiid Thysanoessa macrura, and one salp. In the eastern end of Bransfield Strait a tow contained numerous diatoms plus fairly large numbers of the copepods Oithona similis and large numbers of nauplii, probably belonging to Calanoides acutus.

F. Deep Scattering Layer

1. Introduction

During the cruise the EDO-type fathometer of the ATKA was almost continuously in operation while underway. The resulting fathograms have been analyzed for the presence of the deep scattering layer (DSL) along with notations of geographic location, dates of occurrence, times of descent and ascent, daytime and nighttime levels, extent in miles, and related miscellaneous notes. Aural observations by personnel who supervised the operation of the fathometer contributed pertinent information on the occurrence of the layer.

2. Frequency of Occurrence

The layer appeared on the fathograms of the ATKA during all or part of 36 days--11 out of 49 days in the South Pacific Ocean, 13 out of 35 days in the South Atlantic Ocean, and 12 out of 33 days in the North Atlantic Ocean (see figure 19). In the South Pacific Ocean the layer was not recorded south of about 56° S. or after 10 January. It did not appear at any time while steaming along the entire coast of Antarctica, but reappeared on the fathometer trace on 23 February in the South Atlantic at approximately 62° S. Although the layer was not always recorded on the fathogram in the Atlantic and Pacific Oceans, its presence was evident by listening on most days. The DSL was neither audibly nor visibly present when operating in the Antarctic waters.

3. Diurnal Movement

The fathometer traces usually exhibited the typical diurnal movement, descending at about sunrise and ascending at about sunset. Apparent anomalies in this pattern can probably be attributed to time lag within a time zone, heavily overcast mornings or evenings, or faulty interpretation of poor fathograms.

4. Depth of Deep Scattering Layer

The prevailing daytime depth of the DSL on the majority of the days was 200 fathoms. The DSL was recorded at depths of 225 and 250 fathoms east of New Zealand and at a depth of 275 fathoms south of New Zealand. A double layer was evident on the fathogram of 23 February at about 61° S. in the South Atlantic Ocean, the upper layer being recorded at 175 fathoms and the lower at 350 fathoms. Prevailing depths of 150, 175, and 225 fathoms were recorded during several days, particularly in the Atlantic Ocean. Variations in the depth of the daytime level were evident during the majority of the days that the DSL was observed. Usually the differences were of small magnitude, but variations of 100 fathoms occurred on 2 days and differences of 50 fathoms on several other days.

The DSL was generally recorded over deep water. The minimum bottom depth over which it was found was about 500 fathoms, the maximum about 3,700. A possible reason for the minimum bottom depth limit is the capability of the instrument itself. When recording on the 600-fathom scale, the machine appears either to be unable to record the DSL or records it very poorly. This is perhaps the result of the lower gain setting used on this scale. On several days all evidence of a well-developed layer, which was being recorded with the fathometer set on the 6,000-fathom scale, would disappear when the scale setting was shifted to the 600-fathom scale. One exception to the minimum depth occurred on 9 January off the southeast coast of New Zealand, where a trace was obtained while the fathometer was set at the 600-fathom scale. The bottom depth varied between 250 and 700 fathoms. The trace began at 1335 LST and consisted of intermittent groupings of traces usually appearing at a depth of about 200 fathoms. Toward sunset the traces gradually rose; the last one occurred at about 90 fathoms. The traces appeared similar to those that have been made of schools of fish.

5. Discussion and Comparison With Other Observations

During the daylight hours between the Panama Canal and New Zealand, personnel operating the fathometer reported the DSL nearer the surface on overcast days than on clear days (based on aural observations). However, careful comparison between the daytime DSL depth, as recorded on the fathogram, and the cloud cover observations for the same days

does not show good correlation. Much more extensive and detailed observational data in the same geographical area may be required before such correlations can be made.

The daytime layer trace was frequently masked by a dark or elongated outgoing signal trace, caused either by a high gain setting or reverberation during high seas. This situation made it difficult and often impossible to ascertain the depth, time of descent and ascent, or even the existence of the layer. In figure 19, whenever masking of the daytime layer trace was almost complete, the layer is recorded as present if some evidence of the layer appeared during the day and if the layer were present on the preceding and following days.

Comparison of the characteristics of the layer as recorded by the ATKA in 1954-55, the USS HENDERSON in 1946-47 (Operation HIGHJUMP), and the French Ship COMMANDANT CHARCOT in 1948-49, may be made. A distinct double layer was recorded on only one occasion by the ATKA, whereas numerous double layers and even triple layers were observed aboard the HENDERSON and COMMANDANT CHARCOT. The possible existence of a double layer, of which the lower layer persisted at an unchanged level throughout the night, was noted on the ATKA's fathogram. Such an occurrence was also noted on the HENDERSON. The HENDERSON recorded no DSL for 2 days and a poor development of the layer on 1 day between 10° and 20° S., and 140° and 150° W. in the vicinity of the Marquesas Islands and the Tuamotu Archipelago, where the water was deep enough for development of the layer. It is interesting to note a similar poor development and ultimate disappearance of the layer trace on the ATKA fathogram in the same general mid-Pacific area, although it began about 10° farther south and extended over a longer distance.

The absence of the layer in Antarctic waters as noted on the ATKA fathograms compares well with the results reported from the COMMANDANT CHARCOT, but poorly with those from the HENDERSON. The COMMANDANT CHARCOT did not record the layer at any time south of 62° S. The HENDERSON, however, recorded observations of the layer on a number of days while navigating in Antarctic waters between 61° and 67° S. Generally, the layer was recorded indistinctly and sporadically, but on 2 days it was as well developed as in tropical Pacific waters.

Discrepancies exist among the reported latitudes at which the layer disappeared in Pacific Antarctic waters on each of the three expeditions. Termination of the layer at about 56° S. or about 7° to the north of the Antarctic Convergence was recorded aboard the ATKA. The HENDERSON recorded the temporary termination of DSL when crossing the Antarctic Convergence at about 62° S., whereas on the COMMANDANT CHARCOT the layer was observed until the limit of drifting icepacks was reached at about 64° S. or almost 10° to the south of the convergence at that time.

The only DSL records obtained by the ATKA while crossing the convergence are those for the Atlantic Antarctic Convergence. The layer did not show major differences in depth. Crossing the Pacific Antarctic Convergence, by the HENDERSON, the layer was observed to drop from 300 fathoms to 400 fathoms. A rise of about 135 fathoms by the layer was noted as the COMMANDANT CHARCOT crossed the Subtropical Convergence proceeding northward in the Indian Ocean.

6. Recommendations

From the above comparison of observations of the DSL by the three expeditions, certain features of the layer appear to warrant specific observation on future Antarctic cruises. The fathogram should be closely watched through the mid-Pacific region to see if the DSL is absent for one or more days. Special interest should also be paid to the fathogram when traversing the regions of the Subtropical and Antarctic Convergences, to note any change in prevailing depth or the disappearance of the layer. The possible effect of heavy overcast or fog upon the daytime depth of the layer also should be observed. A close watch should be maintained for the occurrence of the DSL in Antarctic waters south of 60° S. If absent on the fathogram, aural observations should be made possible. The use of the 6,000-fathom scale is preferred when bottom depths allow and when the day-night cycle is in effect.

It appears from this study that there is considerable difference in the resolution factor between various fathometer instruments and between scale settings of the same instrument. This suggests that some attempt should be made to calibrate or evaluate fathometer instruments on some standard so that it will be possible to relate trace records to one another.

G. Results From Snow and Ice Studies

Snow pits were dug in the compacted snow of the shelf ice at several places on both sides of the continent, and ice cores were obtained from the fast ice where possible. Results from tests conducted on snow and ice are reported upon below.

In the Little America area two snow pits were dug at or near the site of Little America III, a 1.9-meter pit over the emergency Quonset radio hut erected in 1947 and a 2.0-meter pit dug 1/12 mile to the east of the camp. The snow surface was relatively smooth and soft; with skis, a man would sink 2 or 3 inches into the surface. Low and infrequent sastrugi crests were exposed throughout the surface drift. There were few crevasses in the area and the general surface was flat with imperceptible changes in elevation. A wind crust was observed

2 to 4 inches below the fresh surface drift. The results of temperature, density, and Rammsonde hardness measurements beneath the snow surface are shown in figure 20. Over the Quonset hut, densities were moderate in the first 60 cm. of the pit and agreed well with the same portion of the pit dug 1/2 mile to the east. In the deeper portions of the latter pit densities increased irregularly to a relatively high figure of between 0.40 and 0.45 gm./cm³. Rammsonde hardness measurements agreed substantially at both pits. Over the hut there was some hardening of the subsurface resulting possibly from reflected solar heat from the side of the hut. Crusts noted in the upper 170 cm. of snow in the east pit were probably caused by wind. Eddy currents probably were responsible for the lack of crusts at the hut pit.

At Kainan Bay, two 1-meter snow pits were dug in the shelf ice to the east of the bay; the pits were 2 miles apart. Temperature, density, and Rammsonde hardness measurements were widely different in the two pits (fig. 21), probably because of local differences in meteorological conditions. Station O is considered to be the more representative of conditions in the interior. Figure 22 shows snow stratigraphy in the two pits. The pit at station O contained much more ice than at the northern station (N-1). The low density at the surface in station N-1 was caused by 7 inches of new snow which fell between the times of digging the two pits.

At Kainan Bay, 7 cores were made in the fast ice of the bay; 3 in a line parallel to the edge of the fast ice near the ship, 1 near a tidal crack at the head of the bay, and 3 along a transverse line running from the northwest to southeast corner of the bay. The thickness of the solid ice ranged from 8.5 to 10.5 feet, the average thickness being about 9.5 feet. Beneath the hard ice there was a layer of 3 to 4 feet of unconsolidated slush ice. The snow cover on the fast ice ranged from 7 inches near the tidal crack to over 25 inches at the western side and averaged about 17 inches. Preliminary field conductivity tests run on samples taken from two core sections at various depths indicated a salt content ranging from 1/7 to 1/14 that of normal sea water. Salinity titrations on the melted samples performed in the oceanographic laboratory of the Hydrographic Office showed salinity to range from 1/6 to 1/16 that of normal sea water. The results of the laboratory salinity determinations at 1-foot intervals throughout the length of cores 2 and 7 are shown in table I. Core number 2 was taken near the edge of the fast ice, core number 7 was taken along the transverse line 2 miles from the edge of the fast ice.

At Atka Bay, there was no fast ice and the shelf ice face was low, averaging from 15 to 40 feet in height above the water. A 2-meter snow pit (station 1) was dug in the shelf ice 6 miles inland, and Rammsonde profiles were obtained. Rammsonde profiles also were obtained at station 2, 10 miles inland. The snow surface was exceptionally smooth

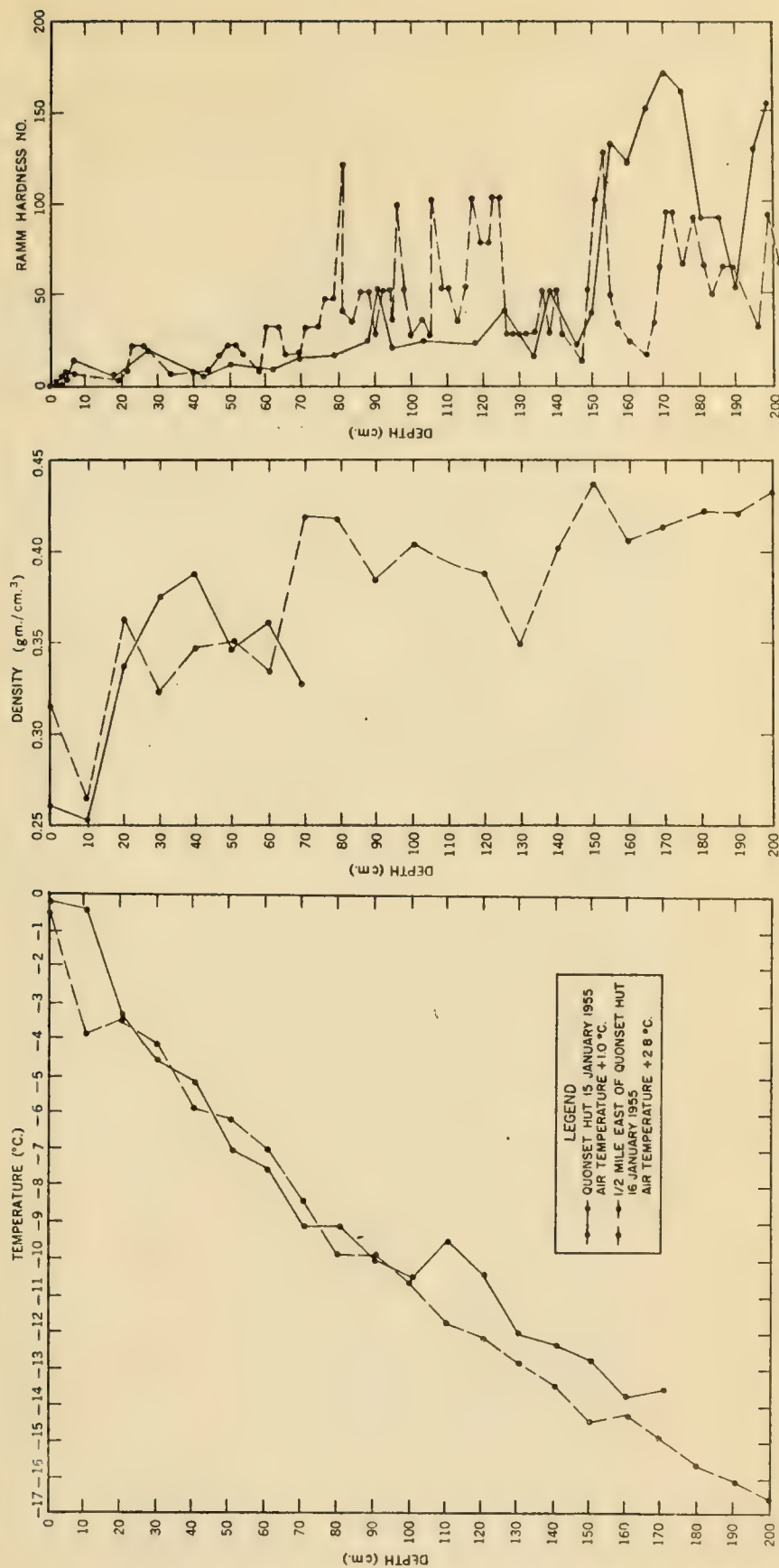


Figure 20. Snow Temperature, Density, and Hardness - Emergency Base, Little America III - 15-16 January 1955.

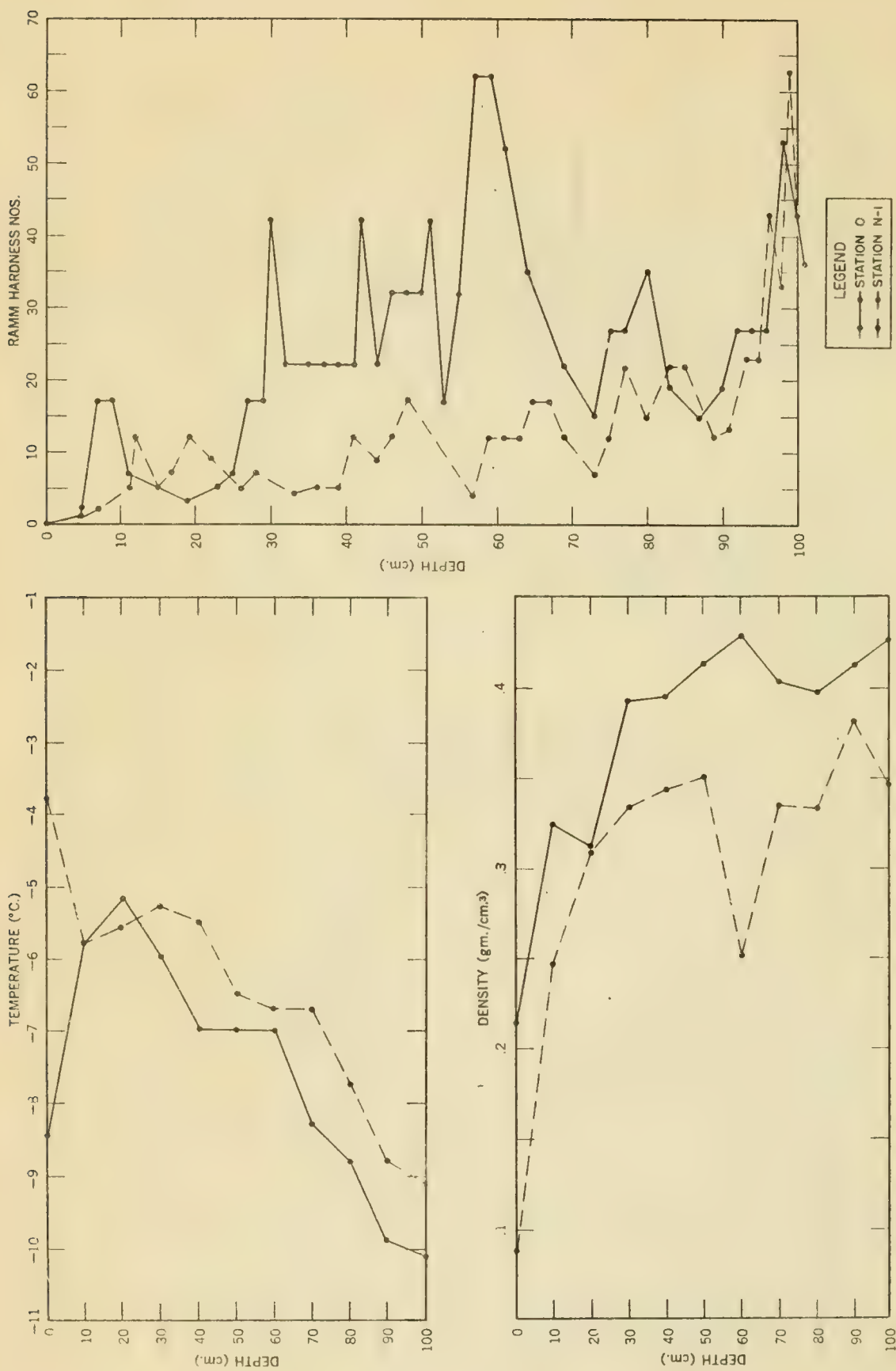


Figure 21. Snow Temperature, Density, and Hardness - Kainan Bay - 22 January 1955.

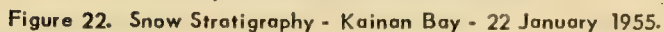


Table I. -- Salinity (‰) of ice core samples at Kainan Bay

<u>Depth (ft.)</u>	<u>Core No. 2</u>	<u>Core No. 7</u>
0-1	3.32	2.70
1-2	4.72	2.09
2-3	5.05	3.24
3-4	4.92	2.95
4-5	4.76	4.76
5-6	4.38	2.74
6-7	4.06	3.10
7-8	5.68	--

(Salinity of surface sea water at edge of fast ice -- 33.46 ‰)

with little evidence of loose or drifting snow. The area was relatively flat with 6-inch sastrugi present, which were probably caused by recent strong winds from the south. Results of temperature, density, and Rammsonde hardness tests are shown in figure 23. A general picture of snow stratigraphy is presented for station 1 (fig. 24). At station 1 the neve was of moderately high density (between 0.4 and 0.5 gm./cm.³) below the first 50 cm. Rammsonde hardness tests showed highly resistant subsurface layers as shown in the stratigraphic picture of the pit. At station 2 there was exceptional hardness as shown by Rammsonde tests 100 cm. below the surface.

Admiral Byrd Bay had about 1/2 mile of fast ice, which was estimated to be from 15 to 20 feet in thickness, at the head of the bay. Along the margins of the bay the shelf ice was from 15 to 50 feet in height. On the south side of the bay a 2-meter snow pit was dug in the neve of the shelf ice 4 miles south of the bay (station 0). The snow surface was level with 12-inch sastrugi present 10 - 20 feet apart. A covering of loose snow from 2 to 6 inches deep was present. Temperature, density, and Rammsonde profiles were obtained at station 0 (fig. 25). Snow stratigraphy at the pit is shown in figure 26. Densities observed in the snow pit (station 0) varied greatly, being very high near the subsurface ice layers and low in the fluffy snow of the surface. Rammsonde profiles also were made at points 1 and 2 miles south, 1 mile east, and 2 miles west of the snow pit. The average hardness profile of the five Admiral Byrd Bay stations is compared with the profile obtained at station 0 in figure 25. An ice layer below a depth of 100 cm. at the snow pit was apparent in the Rammsonde profiles for the other four stations and appeared to be typical of locality. This ice layer provided a hard sub-base in the snow below 100 cm.

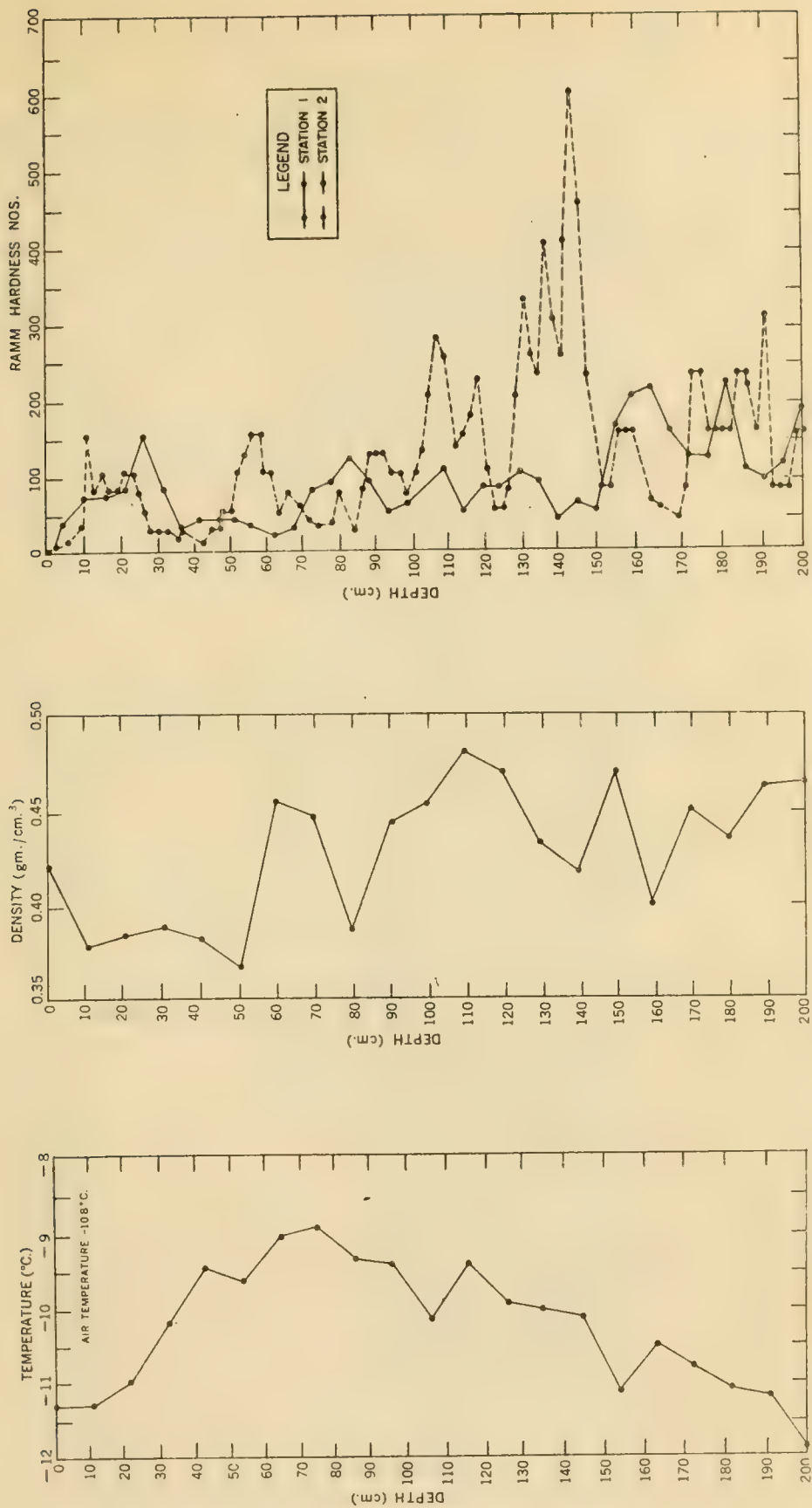


Figure 23. Snow Temperature, Density, and Hardness - Aka Bay - 17 February 1955.

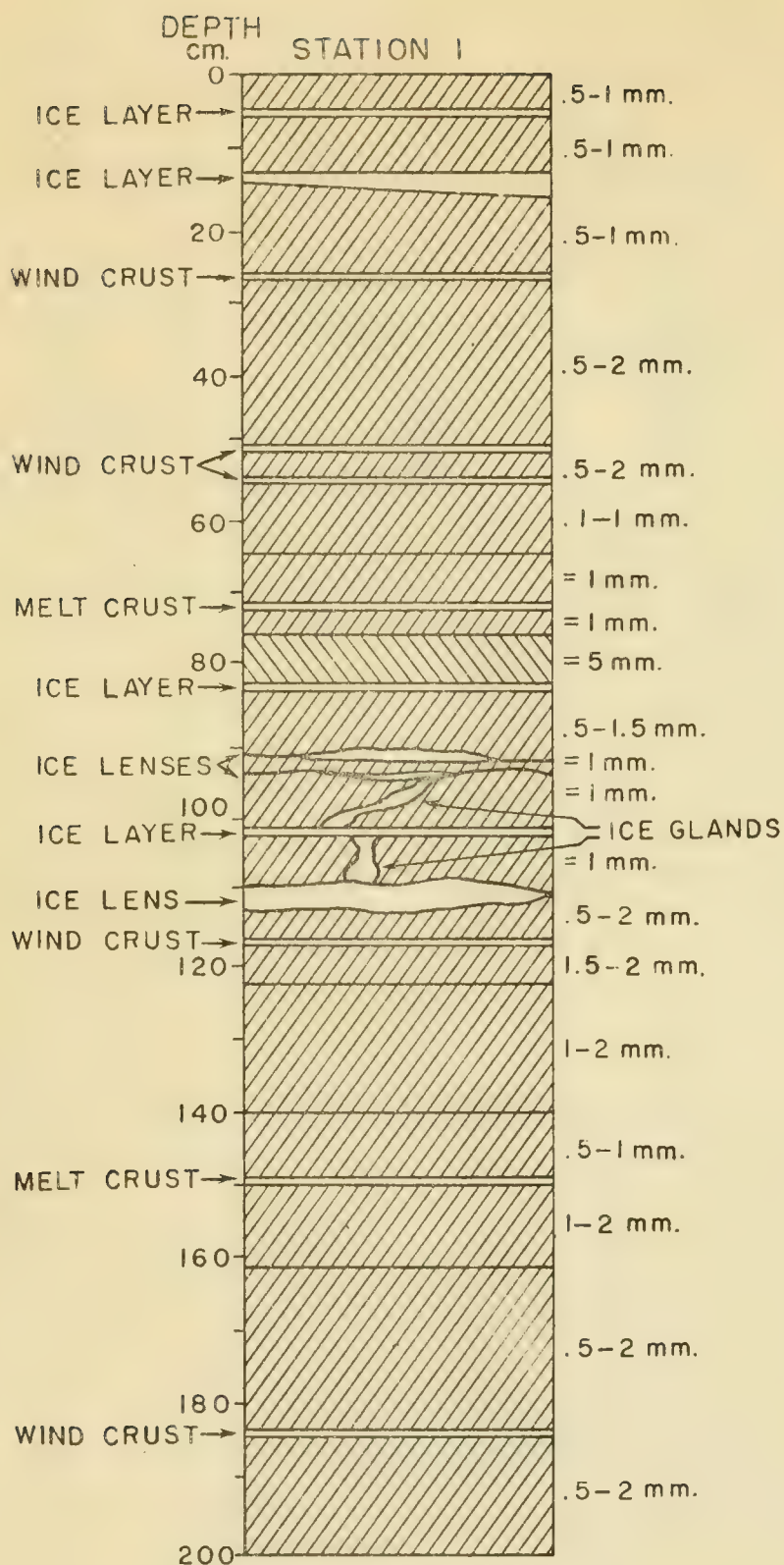


Figure 24. Snow Stratigraphy - Atka Bay - 17 February 1955.



Figure 25. Snow Temperature, Density, and Hardness - Admiral Byrd Bay - 19 February 1955.

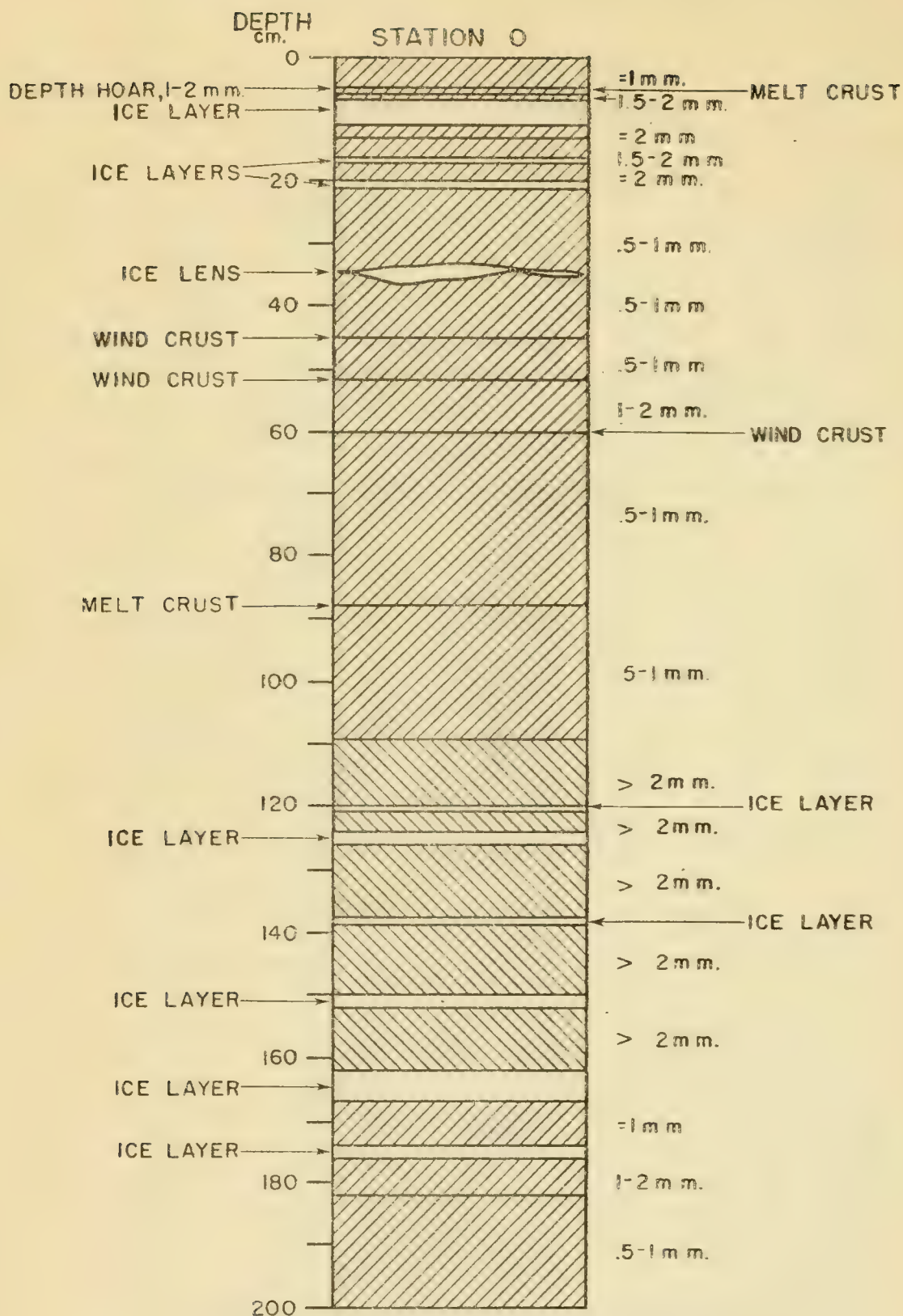


Figure 26. Snow Stratigraphy - Admiral Byrd Bay - 19 February 1955.

One core was attempted in the fast ice at a spot about 100 feet from the edge of the ice. Two snow layers, each about 100 cm. in thickness, were penetrated before the hard ice was reached. These layers were composed of well-packed, coarse-grained granules and were separated by a 2-inch ice layer. The snow was sufficiently consolidated to permit lifting it out in large blocks. Below the snow layers, 5 feet of soft ice was bored through before reaching very hard ice. Here, coring was terminated because of the shearing of the ice auger shaft extension. A second attempt at coring was curtailed by the unexpected departure of the ATKA that evening because of a threatening pack from the north. One soft ice sample taken near the top of the ice core showed a salinity of only 1.70 ‰. This fact together with the accumulation of snow on the ice indicated that this part of the fast ice had been in position for several years.



Plate I. Ross Ice Barrier Near Little America.



Plate II. Ross Ice Barrier West of Little America.



Plate III. Fast Ice in Kainan Bay Looking Southeast.



Plate IV. Head of Kainan Bay Looking Southeast With Tidal Crack in Foreground. Ski Tracks Beyond Tidal Crack Lead to Ramp Onto Shelf Ice.



Plate V. USS ATKA Tied up at Kainan Bay. Low Cloud Bank and Loose Pack Ice in Background. Weasel and Ski Tracks Lead to the Tidal Crack at the Head of the Bay.



Plate VI. Taking Hand Sounding at Tidal Crack, Head of Kainan Bay.



Plate VII. Seven-foot Weddell Seal at Kainan Bay.



Plate VIII. Stormy Appearance of Sky at Kainan Bay.



Plate IX. Wave-worn Caves at Edge of Iceberg Near Cape Colbeck.



Plate X. Open Lead East of Cape Colbeck. Penguins and Hummocked Ice in Background.



Plate XI. Ice Pack East of Cape Colbeck.



Plate XII. Iceberg Driving Through Pack Ice off Southeast Corner of Peter I Island.



Plate XIII. Atka Bay Looking South.



Plate XIV. Wave-worn Caves at Edge of Shelf Ice, Atka Bay.



Plate XV. Removing Core From 80-pound Phleger Corer, Atka Bay.



Plate XVI. USS ATKA Tied up to Fast Ice at Head of Admiral Byrd Bay.



Plate XVII. View From Head of Admiral Byrd Bay Looking West Toward Entrance.



Plate XVIII. View From Head of Admiral Byrd Bay Looking Northeast From USS ATKA.
Fast Ice of Bay in Foreground and Shelf Ice in Background.



Plate XIX. Taking Ice Core in Fast Ice of Admiral Byrd Bay.

U. S. Navy Hydrographic Office

FIELD REPORT, OCEANOGRAPHIC OBSERVATIONS, U. S. NAVY ANTARCTIC EXPEDITION 1954-1955. USS ATKA. March 1956. 82 p. 26 figs. 19 pl. (H.O. Misc. 16331).

Contains the summary and results of oceanographic operations in Antarctic and adjacent waters from the Ross Sea eastward through Bransfield Strait to the Weddell Sea. Data obtained from snow and ice studies on the fast and shelf ice are included. In addition, the Antarctic Convergence is discussed.

ANNEX 1 contains a tabulation of oceanographic data from 13 stations.

1. Antarctica
2. Oceanography - Antarctic
3. Bottom Sediments - Antarctic
4. USS ATKA

i. title: Field Report, Oceanographic Operations, U. S. Navy Antarctic Expedition 1954-1955. USS ATKA.

ii. H. O. Misc. 16331

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ANNEX I

Explanation and Tabulation of Data

U. S. Navy Antarctic Expedition

1954-1955

U.S.S. ATKA (AGB-3)

MARCH 1956

U. S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON, D. C.

EXPLANATION OF DATA PAGES

GENERAL

Each of the items appearing on the data pages is explained below. The vertical arrows shown in some of the column headings indicate the location of decimal points. The presence of an asterisk to the left of the data indicates that data is doubtful, hence it was not used in the construction of the curve from which the interpolated values (standard depth values) were derived. Observed values which were obviously false were omitted entirely.

SURFACE OBSERVATIONS

1. Cruise Number. This number is arbitrarily assigned. It identified the cruise and provides a means of sorting from the IBM files all cards pertaining to that particular cruise. Cruise number 00504 was assigned to the USS ATKA (AGB-3) U. S. Navy Antarctic Expedition 1954-1955. In the present listing the first two zeros are omitted.
2. Station Number. Stations are numbered consecutively, starting with one, at the beginning of each cruise. Therefore, for a complete identification of a particular station, both cruise and station number are necessary.
3. Date. Month and day are given in Arabic numerals. The last three figures of the year are indicated. The hour is Greenwich Mean Time and is that hour nearest to the start of the first cast.
4. Latitude and Longitude. The position of the station is given in degrees and minutes.
5. Sonic Depth. Sonic Depth is the uncorrected sounding for the station, recorded in meters.
6. Maximum Sample Depth. The maximum depth from which a water sample was obtained at the station is given to the nearest 100 meters.
7. Wind. Wind speed is given in meters per second. Direction from which the wind blows is coded in degrees true to the nearest ten degrees. The last zero is omitted. North is 36 on this scale and calm is 0. See Tables Defining Code Symbols - I, Compass Direction Conversion Table for Wind, Sea, and Swell Directions.
8. Anemometer Height. The height of the anemometer above the waterline is given in meters.

9. Barometric Pressure. Barometric pressure is coded in millibars, neglecting the 900 or 1000. Thus, 996 millibars is coded as 96 and 1008 millibars is coded as 08.

10. Air Temperature. Dry bulb and wet bulb temperatures are entered to the nearest tenth of a degree (centigrade). A negative temperature is coded by dropping the minus sign and adding 50; thus -10° is coded as 60.

11. Humidity. The percent of humidity is coded directly, 100 percent being coded as 99.

12. Weather. Weather is coded as indicated under Tables Defining Code Symbols - II, Numerical Weather Codes - Present Weather.

13. Cloud. Cloud type and amount are coded as indicated under Tables Defining Code Symbols - III, Cloud Type and IV, Cloud Amount.

14. Sea. Sea direction and amount are coded as indicated under Tables Defining Code Symbols - V, Sea Amount.

15. Swell. Swell direction and amount are coded as indicated under Tables Defining Code Symbols - VI, Swell Amount.

16. Visibility. Visibility is coded as indicated under Tables Defining Code Symbols - VII, Visibility.

SUBSURFACE OBSERVATIONS

1. Sample Depth. Observed (actual) depth of each sample is given in meters. Interpolated values at standard depths are also given. The standard depths, in meters, are: 0, 10, 20, 30, 50, 75, 100, 150, 200, 250, 300, 400, 500, 600, 800, 1000, 1200, 1500, 2000, 2500, 3000, and thence every 1000 meters.

2. Temperature. The centigrade temperature is given in degrees and hundredths.

3. Salinity. Salinity is given in parts per thousand (by weight) to two decimal places.

4. Sigma-t. To convert to density divide by 1000 and add 1. Thus, a sigma-t value of 22.35 converts to a density of 1.02235.

5. Delta-D. The values in the columns are the anomalies of dynamic depths from the surface to each level in dynamic meters. Each entry is the cumulative sum of the anomalies of dynamic depth of the layer above. These values have been computed for the standard depths only, and serve to identify computed points.

6. Dissolved Oxygen. These values are given in milliliters per liter to two decimal places. Values of 10.00 or above rarely occur and are coded as 9.99.

7. Sound Velocity. Sound velocity is given in feet per second to one decimal place, corrected for pressure at each depth.

TABLES DEFINING CODE SYMBOLS

I. Compass Direction Conversion Table for Wind, Sea, and Swell Directions

<u>Code</u>	<u>Direction</u>
00 -----	Calm
01 -----	5° to 14°
02 -----	15° to 24° NNE
03 -----	25° to 34°
04 -----	35° to 44°
05 -----	45° to 54° NE
06 -----	55° to 64°
07 -----	65° to 74° ENE
08 -----	75° to 84°
09 -----	85° to 94° E
10 -----	95° to 104°
11 -----	105° to 114° ESE
12 -----	115° to 124°
13 -----	125° to 134°
14 -----	135° to 144° SE
15 -----	145° to 154°
16 -----	155° to 164° SSE
17 -----	165° to 174°
18 -----	175° to 184° S
19 -----	185° to 194°
20 -----	195° to 204° SSW
21 -----	205° to 214°
22 -----	215° to 224°
23 -----	225° to 234° SW
24 -----	235° to 244°
25 -----	245° to 254° WSW
26 -----	255° to 264°
27 -----	265° to 274° W
28 -----	275° to 284°
29 -----	285° to 294° WNW
30 -----	295° to 304°
31 -----	305° to 314°
32 -----	315° to 324° NW
33 -----	325° to 334°
34 -----	335° to 344° NNW
35 -----	345° to 354°
36 -----	355° to 4° N

TABLE II. NUMERICAL WEATHER CODES---PRESENT WEATHER

00	01	02	03	04	05	06	07	08	09
Cloud development NOT observed or NOT observable during past hour.	Clouds generally dissolving or becoming less developed during past hour.	State of sky on the whole unchanged during past hour.	Clouds generally forming or developing during past hour.	Visibility reduced by smoke.	Haze.	Widespread dust in suspension in the air, by wind, at time of observation. NOT raised by wind, at time of observation.	Dust or sand raised by wind, at time of observation.	Well developed dust (s) within past hour.	Duststorm or sandstorm within sight of or at station during past hour.
10 Light fog.	11 Patches of shallow fog at station, NOT deeper than 6 feet on land.	12 More or less continuous shallow fog at station, NOT deeper than 6 feet on land.	13 Lightning visible, no thunder heard.	14 Precipitation within sight, but NOT reaching the ground.	15 Precipitation within sight, reaching the ground, but distant from station.	16 Precipitation within sight, reaching the ground, near to but NOT at station.	17 Thunder heard, but no precipitation at the station.	18 Squalls within sight during past hour.	19 Funnel cloud(s) within sight during past hour.
20 Drizzle (NOT freezing and NOT falling as showers) during past hour, but NOT at time of ob.	21 Rain (NOT freezing and NOT falling as showers) during past hour, but NOT at time of ob.	22 Snow (NOT falling as showers) during past hour, but NOT at time of observation.	23 Rain and snow (NOT falling as showers) during past hour, but NOT at time of observation.	24 Freezing drizzle or freezing rain (NOT falling as showers) during past hour, but NOT at time of observation.	25 Showers of rain during past hour, but NOT at time of observation.	26 Showers of snow or rain and snow during past hour, but NOT at time of observation.	27 Showers of hail, or of rain and snow, during past hour, but NOT at time of observation.	28 Fog during past hour, but NOT at time of observation.	29 Thunderstorm (with or without precipitation) during past hour, but NOT at time of observation.
30 Slight or moderate duststorm or sandstorm has decreased during past hour.	31 Slight or moderate duststorm or sandstorm has decreased during past hour.	32 Slight or moderate duststorm or sandstorm has increased during past hour.	33 Severe duststorm or sandstorm, has decreased during past hour.	34 Severe duststorm or sandstorm, no appreciable change during past hour.	35 Severe duststorm or sandstorm, has increased during past hour.	36 Slight or moderate drifting snow, generally low.	37 Heavy drifting snow, generally low.	38 Slight or moderate drifting snow, generally high.	39 Heavy drifting snow, generally high.
40 Fog at distance at time of observation, but NOT at station during past hour.	41 Fog in patches.	42 Fog, sky discernible, has become thinner during past hour.	43 Fog, sky NOT discernible, has become thinner during past hour.	44 Fog, sky discernible, no appreciable change during past hour.	45 Fog, sky NOT discernible, has begun or become thicker during past hour.	46 Fog, sky discernible, has begun or become thicker during past hour.	47 Fog, sky NOT discernible, has begun or become thicker during past hour.	48 Fog, depositing rime, sky not discernible.	49 Fog, depositing rime, sky not discernible.
50 Intermittent drizzle (NOT freezing) slight at time of observation.	51 Continuous drizzle (NOT freezing) slight at time of observation.	52 Intermittent drizzle (NOT freezing) moderate at time of ob.	53 Continuous drizzle (NOT freezing), moderate at time of ob.	54 Intermittent drizzle (NOT freezing), thick at time of observation.	55 Continuous drizzle (NOT freezing), thick at time of observation.	56 Slight freezing drizzle.	57 Moderate or thick freezing drizzle.	58 Drizzle and rain, slight.	59 Drizzle and rain, moderate or heavy.
60 Intermittent rain (NOT freezing), slight at time of observation.	61 Continuous rain (NOT freezing), slight at time of observation.	62 Intermittent rain (NOT freezing), moderate at time of ob.	63 Continuous rain (NOT freezing), moderate at time of observation.	64 Intermittent rain (NOT freezing), heavy at time of observation.	65 Continuous rain (NOT freezing), heavy at time of observation.	66 Slight freezing rain.	67 Moderate or heavy freezing rain.	68 Rain or drizzle and snow, slight.	69 Rain or drizzle and snow, moderate or heavy.
70 Intermittent fall of snowflakes, slight at time of observation.	71 Continuous fall of snowflakes, slight at time of observation.	72 Intermittent fall of snowflakes, moderate at time of observation.	73 Continuous fall of snowflakes, moderate at time of observation.	74 Intermittent fall of snowflakes, heavy at time of observation.	75 Continuous fall of snowflakes, at time of observation.	76 Ice needles (with or without fog).	77 Granular snow (with or without fog).	78 Isolated starlike snow crystals (with or without fog).	79 Ice pellets (sleet, U. S. definition).
80 Slight rain shower(s).	81 Moderate or heavy rain shower(s).	82 Violent rain shower(s).	83 Slight shower(s) of rain and snow mixed.	84 Moderate or heavy shower(s) of rain and snow mixed.	85 Slight snow shower(s).	86 Moderate or heavy snow shower(s).	87 Slight shower(s) of soft or small hail with or without rain or rain and snow mixed.	88 Moderate or heavy shower(s) of soft or small hail with or without rain or rain and snow mixed.	89 Slight shower(s) of hail, with or without rain or rain and snow mixed, not associated with thunder.
90 Moderate or heavy shower(s) of hail with or without rain or rain and snow mixed, not associated with thunder.	91 Slight rain at time of observation, but NOT at time of observation.	92 Moderate or heavy rain at time of ob.; thunderstorm during past hour, but NOT at time of observation.	93 Slight snow or rain and snow mixed or hail at time of observation; thunderstorm during past hour, but not at time of observation.	94 Mod. or heavy snow or rain and snow mixed or hail at time of ob.; thunderstorm during past hour, but NOT at time of observation.	95 Slight or mod. thunderstorm, with or without rain, but with rain and/or snow at time of observation.	96 Slight or moderate thunderstorm, at time of observation.	97 Heavy thunderstorm, without hail, but with rain and/or snow at time of observation.	98 Thunderstorm, with hail at time of observation.	99 Heavy thunderstorm with hail at time of observation.

III. Cloud Type

Code

- 0 Stratus or Fractostratus
- 1 Cirrus
- 2 Cirrostratus
- 3 Cirrocumulus
- 4 Altocumulus
- 5 Altostratus
- 6 Stratuscumulus
- 7 Nimbostratus
- 8 Cumulus or Fractocumulus
- 9 Cumulonimbus

IV. Cloud Amount

Code

- 0 No clouds
- 1 Less than 1/10 or 1/10
- 2 2/10 and 3/10
- 3 4/10
- 4 5/10
- 5 6/10
- 6 7/10 and 8/10
- 7 9/10 and 9/10 plus
- 8 10/10
- 9 Sky obscured

V. Sea Amount

<u>Code</u>	<u>Approximate Height (feet)</u>	<u>Description</u>
0	-----	Calm
1	Less than 1	Smooth
2	1 to 3	Slight
3	3 to 5	Moderate
4	5 to 8	Rough
5	8 to 12	Very rough
6	12 to 20	High
7	20 to 40	Very high
8	40 and over	Mountainous
9	-----	Very rough confused sea

VI. Swell Amount

Code	Approximate Height (feet)	Description	Approximate Length (feet)
0	----	No swell	----
1	1 to 6	Short or Average	0 to 600
2		Long	Above 600
3	6 to 12	Short	0 to 300
4		Moderate Average	300 to 600
5		Long	Above 600
6	Greater than 12	Short	0 to 300
7		High Average	300 to 600
8		Long	Above 600
9	-----	Confused	-----

VII. Visibility

Code

0	Dense Fog	50 yards
1	Thick Fog	200 yards
2	Fog	400 yards
3	Moderate fog	1000 yards
4	Thin fog or mist	1 mile
5	Visibility poor	2 miles
6	Visibility moderate	5 miles
7	Visibility good	10 miles
8	Visibility very good	30 miles
9	Visibility excellent	Over 30 miles

SURFACE OBSERVATIONS											
CRUISE	STATION	DATE				LATITUDE		LONGITUDE		SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH
		MO.	DAY	YR.	HR.	'	'	'	'		

504 000101 15 955 07 78 30S 164 30W 0585 05

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.

7 04 24 78 017 000 73 02 6 7 1 7 7

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S' /..	σ_t	$\Sigma \Delta D$	O ₂ ml/l	V _f

0000	0069	3414	2740	0000		47491
0000	0069	3414	2740			47491
0005	0068	3422	2746			47496
0010	0069	3425	2748	0007		47501
0010	0069	3425	2748			47501
0015	0067	3427	2750			47502
0020	0066	3427	2750	0013		47504
0025	0066	3427	2750			47507
0030	0067	3428	2751	0018		47511
0050	0068	3433	2755	0030		47527
0050	0068	3433	2755			47527
0075	-0065	3436	2764	0042		47339
0100	-0175	3438	2769	0053		47181
0100	-0175	3438	2769			47181
0150	-0175	3442	2773	0072		47213
0200	-0175	3444	2774	0090		47243
0250	-0174	3445	2775	0108		47275
0300	-0174	3445	2775	0125		47305
0300 *	-0208	3445 *	2776			*47250
0400	-0173	3457	2785	0154		47371
0500	-0172	3460	2787	0176		47433
0575	-0172	3460	2787			47478

SURFACE OBSERVATIONS											
CRUISE	STATION	DATE				LATITUDE		LONGITUDE		SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH
		MO.	DAY	YR.	HR.	'	'	'	'		

504 000201 15 955 11 78 21S 165 38W 0549 04

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.

5 10 24 77 006 506 80 02 6 8 1 7 7

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S' /..	σ_t	$\Sigma \Delta D$	O ₂ ml/l	V _f

0000	0012	3414	2743	0000		47404
0000	0012	3414	2743			47404
0005	0015	3418	2746			47413
0010	0011	3416	2744	0007		47409
0010	0011	3416	2744			47409
0020	0013	3419	2747	0013		47420
0025	0015	3420	2747			47426
0030	-0022	3422	2751	0019		47373
0050	-0135	3427	2759	0030		47210
0050	-0135	3427	2759			47210
0075	-0157	3429	2762	0042		47191
0100	-0175	3431	2764	0054		47178
0100	-0175	3431	2764			47178
0150	-0174	3438	2769	0075		47212
0200	-0173	3444	2774	0094		47246
0250	-0173	3448	2777	0111		47278
0300	-0173	3452	2781	0126		47309
0300	-0173	3452	2781			47309
0400	-0175	3456	2784	0152		47367
0475	-0177	3456	2784			47408

SURFACE OBSERVATIONS										
CRUISE	STATION	DATE				LATITUDE	LONGITUDE	SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH	
		MO.	DAY	YR.	HR.					

504 000301 15 955 14 78 07S 166 50W 0603 06

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.

5 03 24 78 008 506 80 02 6 8 1 7 5

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S' / ‰	σ _t	ΣΔD	O ₂ ml/l	V _t

0000	0081	3429	2751	0000		47515
0000	0081	3429	2751			47515
0005	0083	3414	2739			47515
0010	0080	3414	2739	0006		47513
0010	0080	3414	2739			47513
0020	0079	3415	2740	0013		47518
0025	0079	3416	2741			47522
0030	0026	3417	2744	0020		47445
0050	-0134	3420	2754	0032		47209
0050	-0134	3420	2754			47209
0075	-0155	3425	2758	0045		47193
0100	-0174	3429	2762	0058		47179
0100	-0174	3429	2762			47179
0150	-0174	3436	2768	0080		47212
0200	-0174	3442	2773	0099		47244
0250	-0174	3448	2778	0117		47276
0300	-0175	3452	2781	0132		47306
0300		3452				
0400	-0175	3458	2786	0157		47368
0500	-0176	3460	2787	0180		47427
0600	-0176	3458	2786	0201		47485
0600	-0176	3458	2786			47485

SURFACE OBSERVATIONS										
CRUISE	STATION	DATE				LATITUDE	LONGITUDE	SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH	
		MO.	DAY	YR.	HR.	"	"			

504 000401 16 955 09 78 33S 164 32W 0585 04

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.

7 13 24 78 006 506 80 02 6 8 07 7 6

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S' / ‰	σ _t	ΣΔD	O ₂ ml/l	V _t

0000	0051	3407	2735	0000		47461
0000	0051	3407	2735			47461
0004	0051	3407	2735			47463
0008	0049	3407	2735			47462
0010	0038	3407	2736	0007		47447
0020	-0036	3409	2741	0014		47340
0020	* 0311	3409	* 2717			* 47855
0030	-0092	3410	2744	0021		47259
0040	-0135	3411	2746			47198
0050	-0147	3412	2748	0034		47185
0075	-0171	3415	2751	0048		47163
0080	-0175	3416	2752			47160
0100	-0174	3416	2752	0063		47173
0150	-0171	3417	2752	0091		47208
0200	-0169	3417	2752	0119		47241
0243	-0168	3418	2753			47269
0250	-0168	3418	2753	0147		47273
0300	-0168	3419	2754	0174		47303
0400	-0172	3422	2756	0227		47357
0473	-0177	3425	2759			47394

SURFACE OBSERVATIONS											
CRUISE	STATION	DATE				LATITUDE		LONGITUDE		SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH
		MO.	DAY	YR.	HR.	.	.	.	.		

504 000501 20 955 20 78 06S 163 00W 0640 06

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.

1 07 24 18 000 511 79 02 6 8 1 7 7

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S' /..	σ_t	$\Sigma \Delta D$	O ₂ ml/l	V _t

0000	0027	3378	2713	0000		47412
0000	0027	3378	2713			47412
0005	0027	3380	2715			47415
0010	0024	3382	2716	0009		47415
0010	0024	3382	2716			47415
0020	0018	3382	2717	0018		47411
0025	0005	3384	2719			47395
0030	-0040	3389	2725	0027		47331
0050	-0162	3405	2742	0042		47158
0050	-0162	3405	2742			47158
0075	-0163	3412	2748	0058		47174
0100	-0164	3418	2753	0072		47190
0100 *	-0056	3418 *	2749			*47360
0150	-0167	3423	2757	0099		47217
0200	-0169	3430	2763	0124		47247
0250	-0171	3437	2769	0145		47276
0300	-0174	3443	2773	0164		47304
0300	-0174	3443	2773			47304
0400	-0179	3452	2781	0196		47359
0500	-0185	3458	2786	0221		47411
0600	-0191	3460	2788	0242		47462
0600	-0191	3460	2788			47462

SURFACE OBSERVATIONS											
CRUISE	STATION	DATE				LATITUDE		LONGITUDE		SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH
		MO.	DAY	YR.	HR.	.	.	.	.		

504 000601 21 955 05 77 56S 163 09W 0658 06

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.

5 05 24 77 503 511 89 02 6 8 1 7 6

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S' /..	σ_t	$\Sigma \Delta D$	O ₂ ml/l	V _t

0000	0066	3395	2724	0000		47478
0000	0066	3395	2724			47478
0005	0069	3395	2724			47486
0010	0068	3398	2727	0008		47488
0010	0068	3398	2727			47488
0020	0013	3382	2717	0017		47404
0025	-0009	3380	2716			47372
0030	-0020	3394	2728	0025		47364
0050	-0055	3433	2761	0038		47339
0050	-0055	3433	2761			47330
0075	-0058	3430	2759	0051		47347
0100	-0062	3427	2757	0063		47355
0100	-0062	3427	2757			47355
0150	-0068	3427	2757	0090		47375
0200	-0074	3427	2757	0116		47395
0250	-0082	3427	2758	0142		47413
0300	-0091	3428	2759	0167		47429
0300	-0091	3428	2759			47429
0400	-0112	3431	2762	0215		47456
0500	-0137	3436	2767	0259		47478
0600	-0166	3442	2772	0297		47494
0640	-0179	3445	2775			47498

SURFACE OBSERVATIONS											
CRUISE	STATION	DATE				LATITUDE		LONGITUDE		SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH
		MO.	DAY	YR.	HR.	'	'	'	'		

504 000701 23 955 21 78 07S 162 30W 0640 06

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.
5	21	24	84	517	528	78	02	6	8	0				7		7

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S' /..	σ _t	ΣΔD	O ₂ ml/l	V _t
0000	-01.49	33.46	269.4	0000		471.23
0000	-01.49	33.46	269.4			471.23
0005	-01.11	33.51	269.7			471.89
0010	-00.75	33.78	271.8	0010		472.60
0010	-00.75	33.78	271.8			472.60
0020	-00.62	33.90	272.7	0019		472.91
0025	-00.58	33.95	273.1			473.03
0030	-00.54	33.99	273.4	0026		473.14
0050	-00.54	34.13	274.5	0040		473.32
0050	-00.54	34.13	274.5			473.32
0075	-01.15	34.17	275.1	0056		472.53
0100	-01.64	34.20	275.5	0070		471.91
0100	-01.64	34.20	275.5			471.91
0150	-01.37	34.26	275.9	0096		472.66
0200	-01.16	34.32	276.3	0120		473.32
0250	-01.01	34.37	276.6	0142		473.87
0300	-00.93	34.42	277.0	0163		474.32
0300	-00.93	34.42	277.0			474.32
0400	-00.96	34.50	277.7	0199		474.90
0500	-01.25	34.57	278.3	0228		475.06
0600	-01.80	34.61	278.8	0251		474.80
0600	-01.80	34.61	278.8			474.80

SURFACE OBSERVATIONS											
CRUISE	STATION	DATE				LATITUDE		LONGITUDE		SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH
		MO.	DAY	YR.	HR.	'	'	'	'		

504 000802 07 955 07 63 07S 061 21W 0590 05

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.
5	09	24	80	028	017	83	02	6	7	1				7		

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S' /..	σ _t	ΣΔD	O ₂ ml/l	V _t
0000	01.90	33.87	271.0	0000		476.59
0000	01.90	33.87	271.0			476.59
0005	01.89	33.89	271.1			476.62
0010	01.90	33.91	271.3	0010		476.67
0010	01.90	33.91	271.3			476.67
0020	01.85	33.91	271.3	0019		476.66
0025	01.78	33.91	271.4			476.58
0030	01.59	33.91	271.5	0028		476.33
0050	00.90	33.93	272.1	0046		475.43
0050	00.90	33.93	272.1			475.43
0075	00.90	34.03	272.9	0067		475.62
0100	00.91	34.13	273.7	0086		475.83
0100	-00.32	34.13	274.4			473.95
0150	00.92	34.23	274.5	0119		476.18
0200	00.93	34.35	275.5	0149		476.55
0250	00.93	34.46	276.4	0175		476.89
0300	00.93	34.54	277.0	0196		477.22
0300	00.93	34.54	277.0			477.22
0400	00.92	34.65	277.9	0233		477.85
0500	00.91	34.65	277.9	0266		478.42
0575	00.89	34.65	277.9			478.84

SURFACE OBSERVATIONS											
CRUISE	STATION	DATE				LATITUDE		LONGITUDE		SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH
		MO.	DAY	YR.	HR.	°	'	°	'		
504	000902	07	955	12	63	09S	059	34W	0840	08	

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.
7	25	24	82	039	022	76	02	6	8	1				7	11	

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S' /..	σ _t	ΣΔD	O ₂ ml/l	V _f
0000	0205	3413	2729	0000		47692
0000	0205	3413	2729			47692
0005	0198	3414	2731			47685
0010	-0030	3413	2744	0007		47345
0010	-0030	3413	2744			47345
0020	0013	3416	2744	0014		47418
0025	0028	3422	2748			47447
0030	0029	3425	2751	0020		47453
0050	0031	3431	2755	0031		47470
0050	0031	*3507	*2817			*47502
0075	-0010	3440	2765	0044		47426
0100	-0026	3447	2771	0054		47419
0100	-0026	3447	2771			47419
0150	-0033	3448	2772	0073		47438
0200	-0039	3450	2774	0092		47460
0250	-0046	3451	2775	0109		47479
0300	-0052	3452	2776	0127		47500
0400	-0063	3454	2779	0159		47543
0400	-0063	3454	2779			47543
0500	-0073	3456	2781	0189		47588
0600	-0082	3457	2782	0217		47633
0800	-0097	3460	2785	0269		47730
0800	-0097	3460	2785			47730

SURFACE OBSERVATIONS											
CRUISE	STATION	DATE				LATITUDE		LONGITUDE		SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH
		MO.	DAY	YR.	HR.						
504	001002	07	955	20	62	40S	056	53W	0225	02	

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.
6	06	24	83	036	019	75	02	6	2	1				7	12	

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S' /..	σ _t	ΣΔD	O ₂ ml/l	V _f
0000	0032	3445	2767	0000		47448
0000	0032	3445	2767			47448
0005	0034	3452	2772			47457
0010	0024	3454	2774	0004		47445
0010	0024	3454	2774			47445
0015	0023	3499	2811			47466
0020	0025	3494	2806	0006		47470
0025	0026	3488	2802			47472
0030	0025	3477	2793	0007		47469
0050	0015	3447	2769	0013		47452
0050	0015	3447	2769			47452
0075	-0020	3451	2774	0023		47415
0100	-0047	3454	2778	0032		47390
0100	-0047	3454	2778			47390
0150	-0078	3458	2782	0047		47373
0200	-0079	3458	2782	0061		47401
0200	-0079	3458	2782			47401

SURFACE OBSERVATIONS										
CRUISE	STATION	DATE				LATITUDE	LONGITUDE	SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH	
		MO.	DAY	YR.	HR.					

50.4 001102 17 955 20 70 32S 008 04W 0068 01

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.
7	12	24	79	544	561	62	02	6	8	1				7		

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S'/.	σ _t	ΣΔD	O ₂ ml/l	V _t
0000	-0072	3391	2728	0000		47264
0000	-0072	3391	2728			47264
0005	-0065	3391	2728			47278
0010	-0070	3391	2728	0008		47273
0010	-0070	3391	2728			47273
0020	-0069	3397	2733	0016		47283
0025	-0068	3400	2735			47289
0030	-0072	3402	2737	0023		47287
0035	-0075	3404	2739			47286
0040	-0078	3405	2740			47285
0050	-0102	3407	2742	0037		47254
0050	-0102	3407	2742			47254
0065	-0132	3423	2756			47222

SURFACE OBSERVATIONS										
CRUISE	STATION	DATE				LATITUDE	LONGITUDE	SONIC DEPTH UNCORRECTED	MAX. SAMPLE DEPTH	
		MO.	DAY	YR.	HR.					

504 001202 18 955 04 70 23S 008 14W 0823 08

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.
5	11	24	81	556	564	72	02	6	8	1				7		

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C	S'/.	σ _t	ΣΔD	O ₂ ml/l	V _t
0000	-0064	3378	2717	0000		47271
0000	-0064	3378	2717			47271
0005	-0062	3382	2720			47279
0010	-0064	3382	2720	0009		47279
0010	-0064	3382	2720			47279
0020	-0068	3385	2723	0017		47280
0025	*0227	3387	*2707			*47728
0030	-0070	3393	2730	0026		47286
0050	-0075	3402	2737	0041		47294
0050	-0075	3402	2737			47294
0075	-0077	3410	2744	0058		47309
0100	-0079	3418	2750	0073		47324
0100	-0079	3418	2750			47324
0150	-0083	3424	2755	0101		47350
0200	-0087	3429	2759	0127		47376
0250	-0091	3434	2764	0151		47402
0300	-0095	3438	2767	0173		47427
0400	-0103	3445	2773	0212		47477
0400	-0103	3445	2773			47477
0500	-0111	3450	2777	0246		47525
0600	-0118	3454	2781	0276		47576
0800	-0133	3456	2783	0329		47672
0800	-0133	3456	2783			47672

SURFACE OBSERVATIONS										
CRUISE	STATION	DATE				LATITUDE		LONGITUDE		SONIC DEPTH UNCORRECTED
		MO.	DAY	YR.	HR.	'	'	'	'	

504 001302 19 955 13 69 35S 000 44W 2286 22

WIND		ANEMO. HGT.	BAR. PRESS.	AIR TEMP °C		HUMIDITY %	WEATHER	CLOUD		SEA		SWELL		VIS.	WATER	
m/sec	DIR.			DRY ↓	WET ↓			TYPE	AMT.	DIR.	AMT.	DIR.	AMT.		COL.	TRANS.

1 19 24 88 567 572 85 02 0 3 0 7 13

SUBSURFACE OBSERVATIONS						
SAMPLE DEPTH	T °C ↓	S°/.. ↓	σ _t ↓	ΣΔD ↓	O ₂ ml/l ↓	V _t ↓

0000	-01.26	33.39	2688	0000		47157
0000	-01.26	33.39	2688			47157
0005	-00.67	33.40	2687			47253
0010	-01.22	33.40	2689	0012		47170
0010	-01.22	33.40	2689			47170
0020	-01.11	33.44	2691	0023		47195
0025	-01.06	33.46	2693			47206
0030	-01.03	33.46	2693	0035		47214
0050	-00.94	33.48	2694	0057		47241
0050	-00.94	33.48	2694			47241
0075	-01.01	33.63	2706	0084		47251
0100	-01.06	33.75	2716	0108		47263
0100	-01.06	33.75	2716			47263
0150	-01.04	33.85	2724	0151		47301
0200	-01.03	33.98	2735	0190		47338
0200	-01.03	33.98	2735			47338
0250	-01.26	34.19	2753	0222		47340
0300	-01.43	34.34	2765	0247		47349
0300	-01.43	34.34	2765			47349
0400	-01.62	34.43	2773	0286		47382
0400	-01.62	34.43	2773			47382
0500	-01.18	34.45	2773	0321		47512
0500	-01.18	34.45	2773			47512
0600	-00.58	34.54	2778	0354		47670
0600	-00.58	34.54	2778			47670
0800	-00.51	34.67	2789	0407		47805
0800	-00.51	34.67	2789			47805
1000	-00.95	34.67	2790	0446		47855
1000	-00.95	34.67	2790			47855
1200	-00.46	34.67	2788	0485		48050
1500	00.28	34.67	2785	0557		48342
1500	00.28	34.67	2785			48342
2000	01.50	34.65	2775	0729		48821
2000	01.50	34.65	2775			48821
2250		34.67				

